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A COMPARISON OF EXPOSITORY AND HYPOTHETICAL MODES OF TEACHING SCIENCE

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled A COMPARISON OF EXPOSITORY AND HYPOTHETICAL MODES OF TEACHING SCIENCE, submitted by Jesse William George Ivany in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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ABSTRACT

A comparison was made among four treatment groups of the quantity and quality of inquiry elicited following instruction in one of three modes ranging from expositional to hypothetical. Three treatment groups of three grade eight classes each were instructed in the three modes while the fourth group, instructed in the hypothetical mode, was used to study the effect of short term instruction upon conventional classroom behavior.

Expositional and hypothetical instruction was defined in terms of a model based on information processing. The relevant variable for the definition was the amount of visual and audio data concerning a science problem which was supplied students at the beginning of inquiry into the problem. Other relevant variables were controlled as far as possible. For the expositional mode of instruction the complete data processing problem was defined, analyzed and solved by a filmed presentation. The hypothetical mode of instruction left the onus of data searching and processing on the student once the problem situation had been visually presented. An intermediate mode used a filmed presentation which provided visual and audio descriptions of the situation and a statement of the problem to focus the students' inquiry. Following each problem film a tape recording was made of the verbal inquiry in the class.

The hypotheses investigated in this experiment related to:

1. The effect of variation of relevant information input upon the quantity and quality of verbal inquiry.

2. The effect of the different modes of instruction prior to the inquiry periods upon gains made on a traditional measure of achievement.

3. The effect of the different modes of instruction prior to the inquiry periods upon changes on a measure of role perception of students regarding the teaching-learning process especially related to the perception of independence.

4. Relationships which might exist among modes of instruction, science knowledge, pre-experiment achievement, perception of independence, participation during inquiry periods, and sex.

The verbal behavior of students was analyzed in terms of the basic model of the experiment. In addition, the analysis was based upon a traditional measure of achievement (the Achievement Test), a measure of science knowledge and aptitude (the STEP Science Test), and a measure of the students' perceptions of their roles in the teaching-learning process (the Q-Sort Instrument).

It was found that although the quantity of verbal inquiry was slightly related to the amount of information initially supplied, the quality of the verbal inquiry was largely determined by the amount and the kind of relevant data provided the inquirers before the inquiry period. All treatment groups performed equally well on the conventional measure of achievement. The only significant contributors to achievement as revealed by multiple linear regression analysis were the STEP Science Test of knowledge and aptitude in science, and the pre-experiment Achievement Test.

The students' perception of role independence as measured by the Q-Sort Instrument seemed to be unrelated to both the nature of the students' verbal inquiry and to their performance on the achievement test. No change in the scores on the Q-Sort were recorded over the experimental period.

Some of the implications of the results are the following. It would seem that inquiry oriented teaching is not necessarily an inadequate method of covering material in the sense that material should be covered for traditional tests of achievement. However, these tests are not appropriate measures of inquiry behavior. In addition the quality and quantity of verbal inquiry from individual students does not appear to be restricted by low achievement and knowledge scores. There is no support from this experiment for the claim that inquiry should be the preserve of the talented.

The assessment of the quality of the inquiry elicited from all groups gave strong indication that students in grade eight are not disposed to use inquiry procedures in an efficient manner. It appears that some reorientation of attitudes may be required in order that students in secondary schools will learn to inquire in a productive manner. The results of this experiment seem to indicate a need for reemphasis in the manner in which approval and encouragement are awarded during the early school years.

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CHAPTER I

INTRODUCTION

The failure of traditional teaching methods to reach many of the goals of science education, particularly non-cognitive goals, has stimulated much thought in recent years. There appear to be two main schools of thought concerning directives for change. One bases its beliefs in the values of a more socially oriented curriculum.[1] This school urges that science be taught in a more integrated form, perhaps from an historical viewpoint, emphasizing science as a result of human endeavour and underlining the sociological interactions among science technology and culture.

The second school has a psychological orientation. It promotes the teaching of science as inquiry, This group, more seminal than the first, is largely responsible for the ferment of the past decade in high school science.[2] Certain developments in the field of physiological psychology and concurrent theory concerning information processing seem to offer support to those who advocate the teaching of science as inquiry.[3]

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[1]Derek DeSolla Price, "Two Cultures--and One Historian of Science," I. C. Record, 64:527, April, 1963.

[2]Paul DeHart Hurd, "The New Curriculum Movement in Science: An Interpretative Summary," The Science Teacher, 29:6, February, 1961.

[3]J. McV. Hunt, Intelligence and Experience (New York: The Ronald Press Company, 1961), pp. 65-108.

Bruner has expressed the desires of this latter school in a rather vague advocacy of the hypothetical mode of teaching which, it is claimed, leads to the learning of the heuristics of discovery.[4] This style of teaching he compares to a more conventional expositional mode, the principal difference being the source of control of communication in the class, and the way in which this control is exerted. The hypothetical mode of teaching allows greater freedom on the part of the student to direct the flow of information and feedback. Thus, through practice in using an intuitive approach to problems rather than a step by step algorithmic solution styled by an authority, the student learns heuristic methods of discovery.

Much of the past opprobrium attached to terms like problem solving, or discovery, has been warranted, and has perhaps been the result of a necessity for vagueness when defining such terms. Past attempts at translation of heuristic approaches to teaching have been antithetical to the methods and have effectively kept instances of true inquiry in classrooms at a minimum. Heuristic methods are not conducive to algorithmic description.

Apart from psychological evidence, inquiry teaching appears to be the most defensible approach to the teaching of science. The body of scientific knowledge expands at an accelerating rate making ludicrous attempts aimed merely at transmitting content by more efficient methods. Schwab calculates that in fifteen years everything we now know in

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[4] Jerome S. Bruner, "The Act of Discovery," Harvard Educational Review, 31:23, Spring, 1961.

scientific fields will be antiquated.[5] In the face of such a dilemma it appears that more useful is learning how to learn, or, methods of inquiry. With this facility it is possible to comprehend the changing nature of knowledge.

Yet the movement sponsored by those who advocate inquiry teaching is prone to adoption and misinterpretation in a fashion similar to the manner in which were many of Dewey's ideas. A danger exists that any theory of inquiry, however sound it is logically, will become translated into concrete, identifiable steps for the purposes of instruction. Such recipes tend to be used but misunderstood.

In yet another manner, this same danger presents itself. The current concern of the scientist for the elementary teaching of his subject stresses the importance of attitudes. Although the language is similar, the intent is not that of the child-centered progressivist tradition. The affective aspects of learning being emphasized center on a way of looking at a given body of knowledge, a cognitive 'posture' related as much to the inherent logic of a subject as to the interest of the child. Dr. N. W. Hanson, philosopher at Yale University, illuminates this point in stressing that attitudes are:

> Far more important. . . than the cultivation of certain knowledges. . . .When, as now, we turn scientific training into a kind of rehearsal of quantitative magnitudes we lose an opportunity to encourage thought. It's necessary, a little bit,. . . of rote repetition. . . .If we make all scientific education a kind of navel contemplation, an adoption of postures toward problems in

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[5]Joseph J. Schwab, "Some Reflections on Science Education," B.S.C.S. Newsletter, No. 9, p. 8, September, 1961.

> physics, then it gets too much like philosophy. . . .But if _I_ had to put the pedagogical center of gravity somewhere, it would definitely be on the student's attitude.[6]

A paradox is implied in the preceding paragraphs. Teaching science as inquiry is considered advantageous from both psychological and epistemological points of view. But very little is known about how the behavior of teachers should be organized for inquiry, Bruner has suggested that patterns of inquiry, or strategies are experientially determined, and are employed in response to the individual's perception of the situation.[7] Educators, such as Suchman, feel that teaching can be organized to provide the necessary experience for the development of more powerful strategies for learning science.[8] Little is known about student responses to real situations, in group settings, with respect to the kind of situation presented, in particular, the amount of information contained in the situation. Interpretation of inquiry training experiments must be dependent upon such prior knowledge.

The Problem

This study was primarily concerned with answers to the following questions. To what extent is the information contained in a science

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[6] Norwood W. Hanson, "On the Structure of Physical Knowledge," _Education and the Structure of Knowledge_, Fifth Annual Phi Delta Kappa Symposium on Educational Research, Stanley Elam (ed.) (Chicago: Rand McNally & Company, 1964), p. 178.

[7] Jerome S. Bruner, Jacqueline J. Goodnow, and George A. Austin, _A Study of Thinking_ (New York: Science Editions, Inc., 1962), p. 56.

[8] J. Richard Suchman, _The Elementary School Training Program in Scientific Inquiry_ (Urbana, Ill.: College of Education, University of Illinois, January, 1964), pp. 15-29. (Mimeographed.)

problem related to the kinds of strategies adopted by students faced with the task of solution, but who have had no particular "training" in inquiry? Does a varying amount of information input affect the numbers and kinds of questions posed by students? Is there a tendency for students, confronted with problems of a specific amount of information input, to learn in short term more powerful inquiry approaches? Apart from strategies of inquiry, are students able to learn principles and facts of science through inquiry oriented lessons?

Review of models used. Related developments in psychology and cybernetics suggest a model of human problem solving based on the mechanics of information processing.[9] With regard to the teaching of science as inquiry such a model seems useful as a tool for describing and analyzing teacher-learner verbal interaction. Students' ability to utilize and transform information input might well be the focus of interest in teaching by a mode of inquiry rather than the ability to store and retrieve information. This study attempted to compare the effects of modes of teaching which differed in the quantity and quality of information supplied to the student. The major criterion of comparison was not the usual measure of recall of information but a measure of the verbal behavior sampled during class periods. Inherent in such a study are the problems of control of information input, of information feedback, and of the more subtle kinds of communication associated with

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[9] Ibid., pp. 4-12.

affective variables, especially with respect to maintaining an approximation to the normal classroom setting.

An attempt was made to conduct science classes in ways containing essential aspects of the expository and hypothetical modes, as they are referred to by Bruner.[10] These modes of teaching were defined, for this study, in terms of stages of information processing. Related to this intention, a lesson in science may be viewed in the following manner.

A student is confronted with bits of information, or data. In the classroom situation a particular selection of data is presented in some manner by the teacher. Nevertheless, an immediate problem is set for the student in view of the fact that the situation is beladen with both relevant and irrelevant data. Having once selected the appropriate data, the student is faced with assimilation of the elements of the situation as he perceives it, into his pre-existing cognitive structure. Or he may be faced with the more difficult task of accommodating the cognitive structure to an incongruous situation. Implicit in this activity are: determination of relevant data through cue searching; "gating out" of all but the relevant and necessary elements; "testing" the perceived situation by attempts at primitive categorization; assimilation if the test is positive; operation upon the perception of the data, or upon the cognitive structure, or both, if any incongruity is detected. This process is continued until the data can be successfully assimilated.

In teaching by the expository mode, most of these operations are

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[10] Bruner, "The Act of Discovery," op. cit.

performed by the teacher. The student is usually a passive recipient of information, seemingly processed flawlessly by the teacher and thereby given an aura of completeness and certainty. The student is presented with what Schwab terms a "rhetoric of conclusions."[11] In terms of the model, the teacher presents the data, selects the relevant items, may or may not use more than one hypothesis but ultimately suggests the "right" one, and rearranges the data to fit the presented relational concept.

In the hypothetical mode of teaching, as used in this experiment, the teacher merely presents a selection of data. By this process of selection the student is, of course, aided in recognizing relevant data. From this stage, however, the processing of information is completely in the hands of the student. The student is now involved in a decision process. Utilization of the data, identification of relevance and necessity, primitive hypothesis formulation, confirmatory checks upon such attempts, and the final assimilation of data by induction of relational concepts, all must be autonomous. To accomplish this the student may ask questions, perform verbal manipulation of the variables (thought experiments), make inferences and otherwise structure data as he sees fit. One restriction is placed upon him, that his questions be structured so that yes or no answers are appropriate. This forces autonomy of processing upon him. He becomes the controller of informational flow and has an active role in the process unlike his receptive and

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[11] Jospeh J. Schwab, "The Teaching of Science as Enquiry," <u>The Teaching of Science</u>, Joseph J. Schwab and Paul F. Brandwein (The Inglis and Burton Lectures, 1961. Cambridge: Harvard University Press, 1962), pp. 24-25.

passive role in the expositional class.

Another constraint was felt necessary in the selection of lessons to be developed in this manner. In order to provide motivation and maximum assurance that students accustomed to exposition would participate in such a venture, the episodes presented were selected for their "disequilibrating effect." That is, each episode contained information that challenged the student's expectations by confronting him with data which past experience would not have predicted.

Objectives of the Study

The objectives of the study were attained only in the context of a comparison of four treatment groups. The groups were defined according to the amount of information supplied to the student at the beginning of a problem. In addition, one group was given limited instruction regarding the type of behavior felt appropriate to the situation. Comparison among the groups aimed at discovering if differences accrue from varied information input, and from verbal instruction aimed at establishing an appropriate set.

The central purpose was to determine if any relationship exists between the amount of information available to the inquirer and the kind of verbal behavior elicited in problem solution. In consideration of this objective two main hypotheses were formulated.

Hypothesis 1.0 There will be no difference in the amount of autonomous inquiring activity elicited from groups treated with varying amounts of information input relevant to a given problem.

1.1 There will be no difference in the number of questions posed by the groups.

1.2 There will be no difference in the percentage of students participating in the groups.

1.3 There will be no difference in the time demanded for inquiry among the groups.

<u>Hypothesis</u> 2.0 There will be no difference in the <u>quality</u> of autonomous inquiring activity elicited from groups treated with varying amounts of information input relevant to a given problem.

2.1 There will be no difference in the total number of different verbal functions used in the groups.

2.2 There will be no difference in the use of any particular verbal function in the groups.

Although the central consideration was the quantity and quality of verbal behavior in the four treatment groups, some degree of comparison was felt necessary on the basis of more direct cognitive goals. This was especially desirable in view of the fact that although traditional achievement tests stress recall of information, the minimum treatment group was never given this supply of data by a teacher. Any mastery of facts and principles had to be produced as a product of inquiry behavior. A conventional type of achievement test was designed and used as a basis for a third hypothesis in the study.

<u>Hypothesis</u> 3.0 There will be no difference in gain on achievement among groups supplied a varying amount of information relevant to the test when there is opportunity for inquiry to proceed prior to the final examination.

Another concern of the study was the perception of dependence-independence expressed by the student in viewing his own role and in his view of his teacher's perception of the student role. It was felt that some interaction might exist between these variables and achievement or participation in inquiry. This was expected to be especially important in the case of the group given minimum initial information. The

possibility of change in this expression of role perception was suggested by the nature of the new roles assigned in the experiment.

Hypothesis 4.0 There will be no difference among the four groups with respect to the students' expressions of perceived independence.

4.1 There will be no contribution of the students' expression of self-role to achievement among the four groups.

4.2 There will be no contribution of the students' expression of the teachers' view of the student role to achievement among the four groups.

4.3 There will be no difference in the change of students' expression of self-role among the four groups.

4.4 There will be no difference in the change of students' expression of the teachers' view of the student role among the four groups.

A number of other variables were thought to be related to the criteria of achievement, student role perception and teacher role perception. Due to the availability of high speed computing facilities the effects of scientific knowledge, sex and the amount of verbal participation of each student were studied. The following hypotheses were formulated.

Hypothesis 5.0 There will be no contribution to the three major criteria on the basis of sex.

Hypothesis 6.0 There will be no contribution to the three major criteria on the basis of science knowledge as measured by a standardized test of science knowledge and aptitude.

Hypothesis 7.0 There will be no contribution to the three major criteria on the basis of student participation in inquiry during the experiment.

Limitations

This study was not concerned with outlining a method for inquiry teaching. In fact, it was premised on the belief that much information

could be acquired about parts of the inquiry process, and must be, before practical pedagogical implications which are of value can be extracted. Nonetheless, for this study modes of teaching were used which were clearly defined and which, it is felt, contained aspects essential to both expositional and hypothetical modes of teaching. It will be recognized that they are not ideal teaching methods, nor are their adoption at all recommended. They were created in order to study limited aspects of student behavior while strictly controlling the variable under investigation.

Being an attempt at applied research, this study postulated no new theory. In fact, all of the hypotheses tested relate to existing theory. However, throughout the study, a deliberate set was adopted with respect to the validation of some of the basic assumptions.

It would be folly to generalize too liberally from the findings of the study. Although normal classroom conditions were approximated, the study involved a laboratory type of delimitation. Any findings can really be generalized only to such a limited situation. Hypotheses were tested and conclusions formed on the basis of a comparison among four groups created and instructed in manners designed for this study.

Significance of the Study

More must be known about the way students' thinking relates to varying degrees of information input and feedback before a methodology of inquiry can represent more than aborted efforts. While studies have been conducted, for the most part they have suffered on two counts. First they have enunciated a theory of inquiry either too naive or unsound

logically. And second they have tried to solve all parts of the complex teaching-learning problem at once. Empirical knowledge owes its potency to its cumulative nature. Global studies, prematurely attempted, influence little application since they limit potential consumers to commitment to an all-inclusive if inaccurate theory of instruction. Studies aimed at smaller segments of the whole might perhaps be fruitful and at the same time provide effective direction for classroom teachers. The present study represented this approach. It attempted merely to compare qualitatively and quantitatively the verbal behavior of students exposed to modes of teaching varying along a continuum between exposition and inquiry, while strictly controlling other, obviously relevant, variables.

In addition, information theory has not been fully appreciated in terms of its potential value for the study of classroom behavior. This investigation uses a model based on information theory. For this study the difference between inquiry and exposition as modes of teaching was related to the amount of information input. The potency of student participation was measured according to the function of the verbal behavior. For processing of information, it was assumed that certain functions are more powerful than others. Utilization of many different functions was also felt to be a desirable quality.

Another aspect of the study concerned the problem of set in relation to inquiry teaching. Following years of traditional teaching, are students capable of acquiring a new set readily? This problem must be answered to guide any introduction of inquiry techniques into the

schools. It is possible that considerable training or gradual development of inquiry skills from early grades is essential for success with a mode of teaching which greatly emphasizes student participation. This study considered the degree to which students were able to modify their behavior with respect to their responsibility for the flow of information in the classroom.

CHAPTER II

REVIEW OF RELATED LITERATURE

I. SCIENCE EDUCATION

General Background

Almost all areas of study in the high school program have been affected by drastic changes in both content and teaching method. The sciences were among the first of the areas to be reorganized. Here, as in the case of other fields, the changes have been animated by a re-emphasis of certain objectives, in fact, by a reorganization of purposes which indicates, perhaps, a new philosophy of science education. Thus, to comprehend the movement, one must first become aware of the aims of science teaching.

With the understanding that objectives must vary from class to class and from student to student, we nevertheless can identify certain classes of objectives which are relevant to all areas and levels of science teaching. Hurd, writing in the Fifty-Ninth Yearbook of the N.S.S.E., Rethinking Science Education, lists seven such classes.[1] These are objectives directed towards: (1) an understanding of the nature of science; (2) an ability for problem solving in science; (3) an understanding of the social aspects of the scientific enterprise; (4) an appreciation of science; (5) a development of scientific attitudes;

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[1]Paul DeHart Hurd, "Science Education for Changing Times," Rethinking Science Education, Fifty-Ninth Yearbook of the National Society for the Study of Education, Part I (Chicago: University of Chicago Press, 1960), pp. 33-37.

(6) an acquisition of scientific skills and abilities; (7) the identification of career possibilities in science.

Documentation of the evidence that traditional high school science teaching has been neglecting all but a few of the voiced objectives of science education has long been available. Hugh Allen,[2] Mead and Metraux,[3] and the Purdue Opinion Panel[4] have conducted nationwide studies in the United States which have revealed that high school students' understandings of the scientific enterprise are quite inadequate in terms of the present and future roles of scientists in our society. In fact, and more disturbing, these studies indicate that not only are students' understandings of science and scientists inadequate, they are frequently gross distortions of reality. Our science courses are not providing the student with a realistic understanding as a result of his exposure to science taught in the traditional fashion.

A whole spectrum of suggestions regarding needed changes, running from slight reorganization to radical upheaval, has been advanced. The voices of dissatisfaction include those of historians and philosophers who have advocated an approach to science teaching more concerned with the humanitarian dimension. De-Solla Price, noted science historian of Yale, suggests that:

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[2]Hugh Allen Jr., Attitudes of Certain High School Seniors Toward Science and Scientific Careers (Science Manpower Project, Teachers' College. New York: Columbia University Press, 1959).

[3]Margaret Mead and Roland Metraux, "Image of the Scientist Among High School Students," Science, 126:384-390, 1957.

[4]R. W. Heath, et al., "High School Students Look at Science," Purdue Opinion Panel Poll Report Number 50 (Lafayette, Ind.: Division of Educational Reference, Purdue University, 1957).

> Our scientific educational system has grown up in such a way that more than 90% of our citizens are treated as the waste products of a machine for the training of the less-than-10% who are going on to become active scientists. . . .We might well cut from half to three quarters of the science program from the school syllabus, including all laboratory instruction, and devote the time and energy thus saved to the teaching (by historians and other humanists) about science as a human activity.[5]

Less extreme advocates of this approach such as Klopfer and Cooley,[6] base their suggestions on case histories which were developed by Conant[7] for the science in general education program at Harvard. Klopfer and Cooley's secondary school version, called History of Science Cases for High School, has been used in an extensive experiment. These cases may be used within existing courses as units, but draw their material from all fields of science.

In general the historians maintain that owing to the complexity of modern science, and because of the needs of a majority of the school population who will be non-scientists, a general education can best be achieved from a historical approach. In this way simpler material is used. It is argued that the structure of science and the process of inquiry can be illuminated as easily in this way as in any other. Only current 'facts' and 'truths' are eliminated, these being considered of secondary importance.

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[5]Derek DeSolla Price, "Two Cultures--and One Historian of Science," T.C. Record, 64: 527, April, 1963.

[6]Leo E. Klopfer and W. W. Cooley, "The History of Science Cases for High School," Journal of Research in Science Teaching, 1:33-47, 1963.

[7]James B. Conant (ed.), Harvard Case Histories in Experimental Science (Cambridge, Mass.: Harvard University Press, 1957).

Still another remedy which, it is claimed by proponents, would succeed in achieving all the goals of science education is a unified course in science.[8,9] Several recent reports take cognizance of a rising popularity of such courses.[10,11] McKibben, in a paper delivered at the thirty-fourth annual meeting of the National Association for Research in Science Teaching, notes:

> Today a new type of physical science course is becoming popular. The subject matter still contains elements of chemistry and physics. But here the resemblance ends. The new course is an academically sound one for students of greater than average ability. The objective is a greater understanding of the major principles of physical science, rather than a knowledge of the technology of science.[12]

It is worthy of mention that unified science courses embodying the concepts of the newly developed N.S.F. sponsored courses in physics and chemistry are already being used in high schools.[13,14]

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[8]Victor Showalter, "Unified Science--An Alternative to Tradition," The Science Teacher, 31:1:24, February, 1964.

[9]L. L. Slesnick and Victor Showalter, "Program Development in Unified Science," The Science Teacher, 31:1:27, February, 1964.

[10]P. G. Johnson, The Teaching of Science in Public High Schools, U. S. Office of Education, Bulletin Number 9 (Washington: Government Printing Office, 1950).

[11]Robert H. Carleton, "Improving Secondary School Science," Rethinking Science Education, Fifty-Ninth Yearbook of the National Society for the Study of Education, Part I (Chicago: University of Chicago Press, 1960), pp. 152-171.

[12]Margaret J. McKibben, "The Study of New Developments in Secondary School Sciences," Science Education, 45:5:403, December, 1963.

[13]M. R. Lerner, "Integrated Science," The Science Teacher, 31:1:37, February, 1964.

[14]Roy W. Stanhope, "Four Years of School Science for All," The Science Teacher, 31:1:27, February, 1964.

A New Movement

The most dramatic examples of the changes occurring in science education are the new courses in physics, biology, chemistry and earth science, which have been developed with the financial aid of the National Science Foundation.[15] These are the more important in that the various committees have clearly and concisely stated their aims and have underscored what is wrong with traditional courses in their newsletters. All are in agreement that the methods must change.

This "new curriculum movement," as Hurd[16] has named it, has germinated from the belief that science teaching should develop an understanding of the nature of science, its modes of inquiry, and its conceptual inventions. The factors which led to the firm establishment of the movement have been enumerated in a study by Norris.[17] The movement emphasizes three basic postulates regarding the teaching of science. Science teaching should:

> 1. Provide a logical integrated picture of contemporary science: the theories, models and generalizations that picture the unity of science.
>
> 2. Illustrate the diverse processes that are used to produce the conclusions of science and that show the limitations of these methods: the ways of inquiry and the structure of scientific knowledge.
>
> 3. Enable the student at some point to reach the shadow of the frontier: to experience the meaning of "we just don't know" and to be aware of the progress of science.[18]

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[15] A series of articles dealing with each of these new programs is contained in an issue of The School Review, 70:1:1-81.

[16] Paul DeHart Hurd, "The New Curriculum Movement in Science: An Interpretative Summary," The Science Teacher, 29:1:6-9, February, 1961.

[17] Stanley Norris, "Views on Science Education in Foundation Supported Literature" (unpublished Ed.D. thesis, Stanford University, Palo Alto, California, 1962),

[18] Hurd, loc. cit.

This movement will have far-reaching effects on science education if only because it has wedded science to a method of teaching appropriate for our time.

The curriculum movement was an outgrowth of widespread objection by scientists and science educators to the exposition of science as a certain body of fact, one which had lost all contact with the present state of scientific knowledge. One example of this objection is the claim made by Schwab that the basic model for the conventional textbook was laid down at the turn of the century.[19] At that time it represented the state of scientific knowledge of the time and sufficed to meet the needs of the kind of school population for which it was intended. During the past half century, this basic model has been modified to meet the changing needs of a population which has become very diversified but it has not kept pace with the changing state of science. It may be said that the school text has been a restriction on the science curriculum and thereby has controlled, to some extent, teaching method. As a result, high school science has become a superficial history of technology which emphasizes certain fundamental 'laws' and the verification of the experiments of a few great scientists of the past.

Science Teaching as Inquiry

In essence the new movement emphasizes the teaching of science not as factual content or product, but as inquiry. Various authors have

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[19] Joseph J. Schwab, Biology Teacher's Handbook (New York: John Wiley & Sons, Inc., 1963), pp. 4-8.

emphasized the same approach but using terms such as discovery,[20] process,[21] or a way of knowing.[22] Schwab has been one of the foremost theorists of this mode of teaching.[23]

Schwab identifies two dimensions in the teaching of science as inquiry: teaching conducted in a mode of inquiry, and the teaching of science exhibited as inquiry. Thus the teaching of science is in fact an "enquiry into enquiry." Conventionally, science teaching is concerned mainly or wholly with the exposition of a series of unqualified, positive statements. This kind of "rhetoric of conclusions" has the advantage of simplicity and economy of space and time, but it is in part responsible for the false and misleading picture of the scientific enterprise held by many students. Such a rhetoric of conclusions misleads the student in two ways. First it presents a picture of science as consisting of unalterable, fixed truths and second it conveys the impression of science as complete. Yet the present state of science clearly indicates its revisionary character. Science "is a codex, continuously restructured as new data are related to old."[24]

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[20]Jerome S. Bruner, "The Act of Discovery," Harvard Educational Review, 31:22-23, Fall, 1961.

[21]Paul F. Brandwein, "The Strategy of the New Developments in Science Teaching," Convention Proceedings and Addresses, Canadian Education Association (Quebec: Canadian Education Association, September, 1963), p. 41.

[22]Joseph R. Royce, "The Search For Meaning," American Scientist, 47:4, 1959.

[23]Joseph J. Schwab, "The Teaching of Science as Enquiry," The Teaching of Science, Joseph J. Schwab and Paul F. Brandwein (The Inglis And Burton Lectures, Harvard University, 1961. Cambridge, Mass.: Harvard University Press, 1962), pp. 52-73.

[24]Ibid., p. 39.

A new approach to teaching is needed which demonstrates that scientific knowledge is more than a report of observed phenomena. It must show the dependence of these observations upon carefully planned and executed experiments. It must demonstrate that science is an ever growing, self-correcting body of knowledge forged tentatively and slowly from raw materials, that planned experiment and observation arise from problems posed and that these problems, in turn, arise from concepts summarizing earlier knowledge. Again, this new teaching methodology should emphasize a component of doubt, of suspended judgement and a readiness to reconstruct ideas on the basis of new data. Above all teaching must show that our concepts are tested by the fruitfulness of the questions they suggest, and through this testing are continually revised and replaced. Schwab emphasizes that such a teaching approach must pervade all of science teaching:

> Such a completely enquiring classroom requires teaching and learning skills which are not common habits of our schools. Its aim is not only the clarification and inculcation of a body of knowledge but the encouragement and guidance of a process of discovery on the part of the student. . . .Hence, the enquiring classroom is one in which the questions asked are not designed primarily to discover whether the student knows the answer but to exemplify to the student the sorts of questions he must ask of the materials he studies and how to find the answer.[25]

Other noted authors agree with Schwab that the purposes of education in our changing society must be to help the student learn how to learn. Thus he must develop his own methods of data searching and

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[25] Ibid., pp. 65-67.

processing, his own strategies of concept formation.[26,27,28]

One of the most extensive studies of inquiring classrooms was carried out by Suchman in a study of inquiry training in the elementary school, a study referred to previously. Suchman's theory analyzes inquiry as a process in which information is collected and processed and thereby made available for interpretation in the light of presently held concepts, or for modification of presently held concepts in order to assimilate the newly acquired information.[29] These processes of interpretation and modification are what Piaget calls assimilation and accommodation.[30] These functions are central to conceptual growth. Through inquiry children learn to perform them more autonomously.

To facilitate analysis of the growth of ability to inquire due to training, Suchman devised a scheme of measurement based on fluency (the number of questions asked), and frequency of specific question types. The fluency score, it is hoped, corresponds to an index of autonomy. That is, it reflects a child's rate of autonomous decision making and

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[26] Bruner, op. cit., pp. 31-32.

[27] Educational Policies Commission (H. B. Wells, Chairman), Manpower and Education (Washington: National Education Association, 1956).

[28] R. W. Tyler, "The Behavioral Scientist Looks at the Purposes of Science Teaching," Rethinking Science Education, Fifty-Ninth Yearbook of the National Society for the Study of Education, Part I (Chicago: University of Chicago Press, 1960), p. 32.

[29] Richard J. Suchman, The Elementary School Training Program in Scientific Inquiry, U. S. Office of Education Title VII Project Number 216 (Urbana, Ill.: University of Illinois, June, 1962), pp. 4-12.

[30] Jean Piaget, The Psychology of Intelligence, trans. M. Piercy and D. E. Berlyne (London: Routledge & Kegan Paul, 1950), p. 7.

ideational output. The frequency score is dependent on placing each question into a category according to its function. Suchman identifies eleven mutually exclusive categories which can be arranged into the hierarchical organization that follows:

I. Verification
  A. Categorical
    i. Nominal
    ii. Normative
  B. Analytical
    i. Condition--descriptive
    ii. Condition--comparative
    iii. Structural--component
    iv. Properties check

II. Implication
  A. Abstract--conceptual
    i. Diffuse
    ii. Directed
  B. Concrete--inferential
    i. Elimination
    ii. Substitution
    iii. Addition
  C. Concrete--conceptual

This organization will be fully explained in Chapter IV.

In order that the sample of questions asked by a student may be analyzed according to Suchman's scheme it is necessary that his queries be structured to be answerable by 'yes' or 'no'. This tends to force the inquirers to focus and structure questions and avoid open-ended or ambiguous ones. The role imposed on the teacher prevents exposition of a concept and allows only reinforcement of independent searching behavior. Thus the student is helped to develop some of the operations and skills of inquiry. The inquirer is able to obtain information from his teacher in accordance with his informational needs of the moment. This could be cited as a strength for the verbal medium of inquiry.

Another strength might be the greater reliability and directness of following the attempts of the student to solve a problem. In the laboratory the student asks questions by actually performing experiments and noting the results. Usually this type of inquiry is far from autonomous and is always difficult to evaluate.

Laboratory evaluation techniques have concerned educators both at high school and university levels. While the importance of laboratory work in science courses is practically unchallenged, only rare attempts have been made to measure achievement in the laboratory. A review of research literature reveals one series of studies conducted by Krugluk dealing with validation of laboratory evaluation instruments.[31] From these studies, the investigator concluded that performance tests only are reliable measures of the creative aspects of achievement concerned with the operational character of physics. Such restrictions on measurement of laboratory objectives in science teaching are prohibitive.

Miller adds support to the idea of the language medium for inquiry:

> One of the nonsocial consequences of language is the user's ability to talk to himself. This ability aids him to pose and to solve problems. By means of the language a problem can be described with a set of symbols. The symbols can be manipulated more easily and rapidly than the components of the original problem; many solutions can be tried symbolically before any action is taken. This is not to say that all thinking is verbal manipulation; but certainly the results of thinking are influenced by our symbolic acts. . . .Thinking is never more precise than the language it uses. Even if it is, the additional precision is lost as soon as

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[31] H. Kruglak and C. N. Wall, Laboratory Performance Tests for General Physics (Kalamazoo, Michigan: Western Michigan University, 1959), pp. 158-159.

we try to communicate the thought to someone else.[32]

Not all authors agree that inquiry is the most valid objective of science teaching. One of the most formidable opponents is David P. Ausubel. He distinguishes between two types of learning, reception learning and discovery learning.[33,34] Ausubel believes that most classroom learning is organized along the lines of reception learning, wherein independent discovery of what is to be learned is not required. The content of the learning task is typically presented and has only to be internalized and made available (functionally reproducible) for future use. In fact, claims Ausubel, at no stage of development does a learner <u>have</u> to discover principles independently in order to be able to understand and use them meaningfully. Thus, for the sake of efficiency, he claims the superiority of verbal reception learning.

The fallacy in his argument is in assigning to discovery a role parallel with verbal learning, in the meaningful learning of substantive content. If this were the case his claim would be justified. But in fact the additional role of inquiry is presented as that of developing certain attitudes, values and habits, whatever the content being considered. And again, Ausubel's charges are discredited except as we accept as the only aim of science teaching the supply of information to

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[32]George A. Miller, <u>Language and Communication</u> (New York: Science Editions, Inc., 1963), p. 223.

[33]David P. Ausubel, <u>The Psychology of Meaningful Verbal Learning</u> (New York: Grune & Stratton, 1963), pp. 139-172.

[34]David P. Ausubel, "In Defense of Verbal Learning," <u>Educational Theory</u>, 11:15-25, 1961.

students. There is certainly no consensus regarding this point.

Research in the Teaching of Science as Inquiry

From this theory of science teaching stem many implications for the teaching-learning process as it relates to science education. However, very few of these have been investigated. A dearth of studies regarding learning in science has been noted.[35,36] A few studies have shown that research into the teaching of science in a new way can be productive.

In a 1961 study, Neal reported some success from having children in grades one through six engage in aspects of inquiry.[37] Five steps of inquiry were used in the study: stating problems, collecting data, hypothesizing, generalizing, and applying concepts. She recommended attempts to identify techniques to develop specific skills at specific grade levels. In a study conducted in 1961, Butts found that the ability of children to conceptualize solely from concrete manipulation was limited.[38] Scandura compared relative merits of an exposition method

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[35]National Association for Research in Science Teaching, Review of Research Studies in Science Education (Report prepared by the Secondary Level Committee, 1961-1963. Science and Mathematics Teaching Center, Michigan State University, 1964). (Mimeographed.)

[36]Fletcher G. Watson and William W. Cooley, "Needed Research in Science Education," Rethinking Science Education, op. cit., p. 297.

[37]Louise A. Neal, "Techniques for Developing Methods of Scientific Inquiry in Children in Grades One Through Six," Science Education, 45:4:313, 1961.

[38]David P. Butts, "The Degree to Which Children Conceptualize from Science Experiences," Journal of Research in Science Teaching, 1:135-143, 1963.

and a discovery method of instruction with regard to specific and non-specific transfer using fourth, fifth and sixth grade classes.[39] No clear results in favour of either method were obtained. In one of the more successful attempts, Suchman, in the study already mentioned, found that a deliberate program of inquiry training could be valuable in elementary science.[40]

II. EDUCATIONAL PSYCHOLOGY

In the last decade or so, cognitive theorists have gained considerable support from two fields of research. Studies in both the field of cybernetics and the field of neuro-physiology have provided breakthroughs which lend support to an interpretation of behavior far more complex than simple stimulus-response paradigms.

Cybernetics

Analogies between the behavior of machines and of humans have become quite popular. In the words of Norbert Weiner:

> It is my thesis that the physical functioning of the living individual and the operation of some of the newer communication machines are precisely parallel in their analogous attempts to control entropy through feedback. Both of them have sensory receptors as one stage of their cycle of operation: that is, in both of them there exists a special apparatus for collecting information from the outer world at low energy levels, and for making it available in the operation of the individual or of the

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[39] Joseph M. Scandura, "The Teaching-Learning Process: An Exploratory Investigation of Exposition and Discovery Modes of Problem Solving Instruction" (unpublished Ph.D. dissertation, University of Syracuse, Syracuse, New York, 1962).

[40] Suchman, op. cit., pp. 76-81.

> the machine. In both cases these external messages are not taken in _neat_, but through the internal transforming powers of the apparatus, whether it be alive or dead. The information is then turned into a new form available for new stages of performance. In both the animal and the machine this performance is made to be effective on the outer world. In both of them, their _performed_ action on the outer world, and not merely their _intended_ action, is reported back to the central regulatory apparatus.[41]

Many instances are reported of computers programmed to do spectacular tasks. Bernstein and Roberts[42] report on a computer which outplays human opponents in a game of chess. Miller reports a program that was prepared by Gelernter and Rochester and which could read drawings and prove geometry theorems by drawing its own experimental figures.[43]

Theories of learning have benefited most from the use of computers programmed to simulate human problem solving behaviour. Such a program must be precise in its description of such behavior in terms of prior knowledge which a human possesses, of the sequence of steps by which he proceeds to a solution, and of the human shortcomings and strengths of memory and decision making. In order to reach such precision the human version of this process had to be observed carefully and recorded. And finally, through the improvement of such programs following experimentation, a sizeable body of theory regarding human learning has been established. One review of the successes in this field is presented in an

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[41] Norbert Weiner, _The Human Use of Human Beings_ (Boston: Houghton-Mifflin Company, 1954), pp. 26-27.

[42] A. Bernstein and M. DeV. Roberts, "Computer Vs. Chess Player," _Scientific American_, 198:96-105, June, 1958.

[43] G. A. Miller, E. Galanter and K. H. Pribram, _Plans and the Structure of Behavior_ (New York: Henry Holt and Company, 1960).

article by Hovland.[44]

One of the more fruitful series of researches in this area has been directed by Newell.[45,46] Using a hierarchical list structure he has developed programs for computer simulation of human thought processes. One example of such a program is called Logic Theorist. Using this program for proving theorems in logic, the computer behaves qualitatively very like a human being confronted by such tasks. For example, the operations exhibit preparatory and directional set, insight, use of concepts, and the use of a hierarchy of processes. Newell and his colleagues point out that Logic Theorist, or any such program, is in essence a theory of how a human might solve a particular type of problem. Programs like this one differ widely, one from the other, but they share one common feature. Rather than using random transformations of input to output data, they apply transformations which, in the experience of their designers, are known to be helpful in handling certain problems in the given area. That is, they are not, strictly speaking, algorithmic.

Based on such studies as this, Miller, Galanter and Pribram have been led to speculate on a theory of behavior using the approach of

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[44] Carl I. Hovland, "Computer Simulation of Thinking," American Psychologist, 15:687-693, 1960.

[45] A. Newell, J. C. Shaw, and H. A. Simon, "Elements in a Theory of Human Problem Solving," Psychological Review, 65:151-166, 1958.

[46] A. Newell and H. A. Simon, "Computer Simulation of Human Thinking," Science, 134:2011-2017, December 22, 1961.

information processing.[47] The success of the Newell studies was largely responsible for the adoption of hierarchical listing as a basic form of organization in human problem solving.

The basic postulate in such a theory of behavior is that the S-R paradigm of behavior is too simple for most human activity and should be replaced by one which has been called the "cybernetic hypothesis." This states that the fundamental building block of the nervous system is a feedback loop. We can think of this loop as a Test-Operate-Test-Exit unit, or simply, a TOTE, which becomes the fundamental unit of behavior. A simple diagrammatic representation of such a loop as depicted by Hunt is seen in Figure 1.[48]

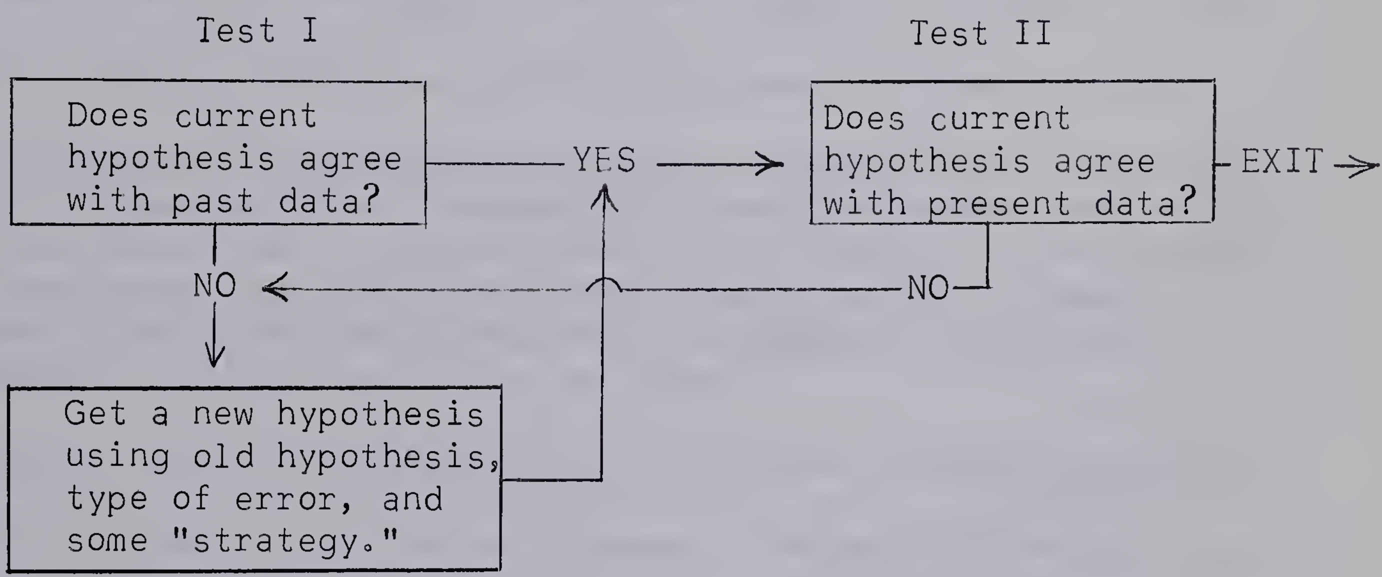

Figure 1. Schematic TOTE Unit.

One value of the computer model of behavior to the science teacher is to explain how a science learning situation may be viewed as

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[47]G. A. Miller, E. Galanter and K. H. Pribram, op. cit., pp. 21-39.

[48]Earl B. Hunt, Concept Learning: An Information Processing Problem (New York: John Wiley & Sons, Inc., 1962), p. 162.

an information processing problem. The role of the teacher, consonant with the idea of inquiry teaching, is to assist the student in developing plans, strategies, and tactics which help him assimilate information in as efficient a manner as possible.

Neuro-Physiology

Computer simulation models of human thinking in psychological theory appear to be gaining support from neurological research. As early as 1949, Hebb proposed a neuro-physiological theory of behavior, speculatively based on research in that field and upon observations of behavior.[49] This theory is quite compatible with the hypotheses of Miller, Galanter and Pribram.

The bases for the Image of Miller's theory could well be the network of cell-assemblies which Hebb proposes. In Hebb's words:

> A repeated stimulation of specific receptors will lead slowly to the formation of an 'assembly' of association-area cells which can act briefly as a closed system after stimulation has ceased; this prolongs the time during which the structural changes of learning can occur and constitutes the simplest instance of a representative process (image or idea).[50]

When certain cell-assemblies are affected frequently and simultaneously by stimuli from the environment, the activity results in an integrated system of the assemblies affected. The new superordinate system would be, essentially, a new assembly since there would be growth through fractionation and recruitment of cells. Activity in any one of the subordinate cell-assemblies so united would facilitate arousal of

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[49] D. O. Hebb, Organization of Behavior (New York: Science Editions Inc., 1961), pp. 60 ff.

[50] Ibid., p. 60.

all others with appropriate motor elements to bring about such arousal. Such a series of arousals of cell-assemblies is termed by Hebb a "phase sequence." Such a phase sequence might, for example, behave as a complex representation of a perception, the individual cell-assemblies being equivalent to elements of the perceptual pattern, the integrated phase sequence the Gestalt completion of perception.

Such cell-assemblies and phase sequences could serve as the neurological equipment needed to establish the images and plans which were proposed in Miller's book. The test stage in the TOTE unit is in essence a comparison between the input stimulus and the internal representation of it. The difference between input and representation is analogous to the incongruity which the organism strives to reduce, providing at some point in time a restructured image.

Strategies in Concept Attainment

Also quite compatible with an information processing theory of cognition are the results of studies reported by Bruner, Goodnow, and Austin. These authors describe experiments carried out with adult humans. Their findings indicate that humans adopt certain "strategies" in attempting to assimilate information. The kind of strategy employed in a particular case depends upon the type of concept. A strategy, in such a context, is a particular program or plan, to use the terminology from above, for collecting and operating on the data supplied. Bruner describes it in this manner.

> A strategy refers to a pattern of decisions in the acquisition, retention, and utilization of information that serves to meet certain objectives, i.e, to insure certain forms of outcome and to

> insure against certain others. Among the objectives of a strategy are the following: (a) To insure that the concept will be attained with certainty after the minimum number of encounters with relevant instances. (b) To insure that the concept will be attained, regardless of the number of instances one must test _en route_ to the attainment. (c) To minimize the amount of strain on inference and memory capacity while at the same time insuring that the concept will be attained. (d) To minimize the number of wrong categorizations prior to attaining the concept.[51]

A strategy need not be a conscious plan but it is inferred from observation of goal-directed behavior.

Bruner identifies three kinds of concept which have been defined by logicians. A conjunctive concept is one defined by the presence _together_ of the appropriate value of more than one attribute. Disjunctive concepts include as members of the class, elements having any one of several appropriate attributes. A relational concept is one in which class members have certain attributes in constant relation to one another.

In the experiments described the concepts were defined by attributes of number, colour, shape and spatial pattern. A subject was shown one example of a class and asked to guess whether other samples were also members of the class. He was informed of the correctness of his guess. The investigators were interested in the strategies or cognitive styles adopted by the subjects. Four different patterns were identified: _Simultaneous scanning_, the systematic trial of alternative hypotheses in a sequence dependent upon results of previous guesses; _Successive scanning_, the trial of one hypothesis at a time in a fashion more

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[51] Jerome S. Bruner, J. J. Goodnow and G. A. Austin, _A Study of Thinking_ (New York: John Wiley & Sons Inc., 1956), p. 54.

unsystematic than above with full benefit not made of information from previous trials with the result that some trials were redundant or inconsistent; Conservative focussing, a trial of conservative variations of the selected focus or positive instance; Focus gambling, drastic changes in the focus, or hit and miss procedures, made in the hope of hitting upon criterial attributes of the class by elimination.

Several general findings of this group of studies have relevance to the present investigation. It was found that the strategy used to pattern decisions in concept attainment was dependent upon a number of factors: (a) The perception which the individual had of the task and his relation to it. (b) The nature of the instances of the concept which were presented. (c) The sequence and ease of validation of the various steps. (d) The risk inherent in a given categorization. (e) The restrictions placed upon the individual. All of these factors have relevance for an individual placed in an inquiry situation in a school classroom.

One criticism of the amount of generalization which has been attempted from the results of the studies of Bruner et al has been levelled at the superficiality of the concepts used. Carroll points out that:

> There are, however, kinds of concept attainment task where the concepts are so difficult or the attributes so lacking in salience that learning is gradual and hypotheses seem of no avail. In such cases, subjects find they must resort to "spectator behavior," simply waiting for the presentation to suggest suitable hypotheses.[52]

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[52]John B. Carroll, Language and Thought (Englewood Cliffs, N.J.: Prentice-Hall Inc., 1964), p. 84.

Expository and Hypothetical Modes of Teaching

For many years educators and psychologists have investigated the relative efficiency of learning stimulated by two extremes of teaching reflecting more or less teacher direction. Such learning has been referred to as directed and independent learning. Bruner elaborates upon the two extremes as the expository and hypothetical modes of teaching. In the expository mode:

> Decisions concerning the mode and pace and style of exposition are principally determined by the teacher as expositor; the student is the listener. . . .But in the hypothetical mode the teacher and the student are in a more cooperative position in respect to what in linguistics would be called "speaker's decisions." The student is not a bench-bound listener, but is taking part in the formulation and at times may play the principal role in it. He will be aware of alternatives and may even have an "as if" attitude toward these and, as he receives information, he may evaluate it as it comes.[53]

Bruner claims benefits which accrue only from the hypothetical mode of teaching. Among these he lists increase in intellectual potency through growth in the attitude of expectancy and methods of search, a shift from extrinsic to instrinsic rewards thus freeing the learner from conformism and stimulating creativity, the learning of the heuristics of discovery through concentration on method rather than product of discovery, and ease of memory processing through organization as a key to memory retrieval.

Schwab is concerned with much the same mode of teaching when he elaborates upon his idea of the completely inquiring classroom.

> For the student, this means relinquishment of habits of passivity, docile learning, and dependence on teacher and textbook, in

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[53]Bruner, op. cit., p. 23.

> favor of an active learning in which lecture and textbook are challenged. The lecture and textbook cease to be authoritative sources of information to be learned and become materials to be dissected, analyzed. For in one form or another, the materials of such a classroom are not statements of truth but reports of enquiry. Hence the student's attention is not on something said but on something done. . . .
>
> In the dogmatic classroom the role of the teacher was to explain what the book left unclear and to test the student's grasp of what he was told. Now, his role is to teach the student how to learn. His responsibility is to impart to the student an art, a skill, by means of which the student can teach himself. This art consists in knowing what questions to ask of a report of enquiry, when to ask them, and where to find the answers. This kind of skill is learned by doing, by exercise, and is taught by guiding the doing.[54]

Both of these modes of teaching and a wide range of modes in between have at times been propounded and justified by various investigators. Several studies in this area have been conducted since 1955, and this activity seems to parallel the activity in the science curriculum area which is leading to courses employing discovery methods. For Schwab, the term discovery referred to a feeling-state arrived at by a learner when, having engaged in inquiry, a sudden understanding is attained. However, much of the research into guided versus independent discovery refers to discovery as the total process of the inquiry, up to and including the sudden comprehension. For instance, one author states:

> The term 'discovery' frequently describes a learner's goal-directed behavior when he is forced to complete a learning task without help from the teacher. . . .If the learner completes the task with little or no help, he is said to have learned by discovery. The most significant teaching variable is the amount of guidance or direction provided by the teacher during the discovery process. In practice, considerable help from the teacher may be provided and still the learner may be said to have learned by discovery, but in such instances the process is usually qualified and called guided

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[54] Schwab, op. cit., pp. 66-67.

> discovery. As the amount of help from the teacher increases, it is said that opportunity for discovery decreases and the learner may rely on rote processes.[55]

Thus, as implied above, much of the problem of interpreting research in this area pertains to the lack of consistency in the terminology used by the investigators. What is called an "intermediate" amount of direction in one experiment may actually exceed the "maximum" amount in another study. Faced with this dilemma, Wittrock was led to conclude that until important stimulus parameters are known, labels for the stimuli should be descriptive.[56]

Katona identified two ways of learning, memorizing and understanding through organizing.[57] Using what have become known as "Katona card tricks" he investigated their relative merits and found organizing superior in terms of retention and transfer. In a further series of experiments using matching tasks, he found that memorizing brought about a small amount of transfer only if the test came immediately after the learning. On the other hand, the discovery group demonstrated an ability to solve old and new tasks equally well after three weeks.

Hendrix, in 1947, reported a series of experiments using three treatments: I--the generalization was stated by the teacher, then

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[55] Bert Y Kersh and Merle C. Wittrock, "Learning by Discovery: An Interpretation of Recent Research," Journal of Teacher Education, 13:4:461, 1962.

[56] Merle C. Wittrock, "Verbal Stimuli in Concept Formation--Learning by Discovery," Journal of Educational Psychology, 54:4:183, 1953.

[57] George Katona, Organizing and Memorizing (New York: Columbia University Press, 1940).

applied to sample problems; II--a method of conscious generalization, the student having arrived at the generalization as indicated by behavior is asked to verbalize the principle; III--a method of unverbalized awareness, the student having arrived at the generalization as indicated by behavior is considered as having finished the learning task.[58] On the basis of the experiments, Hendrix concluded that for transfer power, unverbalized awareness was better. Verbalizing the principle decreased transfer.

Craig conducted two sets of experiments on the basis of a belief that proponents of independent discovery were interpreting their findings too broadly.[59] It had been implied that the more freedom of activity and hence the less teacher guidance, the better. Two groups of college students were given verbal problems containing five words, four of which were related. The Independent Group was given immediate knowledge of the success of their choices through the design of the instrument. The Directed Group was given a short verbal statement of the underlying relationship. Craig's results tended to confirm Thorndike's conclusion that "the widespread limitation of guidance. . .to designating errors, is a sign of weakness in the technique of teaching."[60] Using similar materials, Craig reports Stacey found specification of

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[58]Gertrude Hendrix, "A New Clue to the Transfer of Training," Elementary School Journal, 48:4:197, December, 1947.

[59]Robert C. Craig, "Directed Versus Independent Discovery of Established Relations," Journal of Educational Psychology, 47:223, 1956.

[60]E. L. Thorndike, The Psychology of Wants, Interests and Attitudes (New York: Appleton-Century Company, 1935). p.147.

correct answers in advance of pupil activity to be inferior to merely designating errors.[61] Craig felt that the explanation for the apparently conflicting results was that guidance really helped students, but answers given too early short circuit searching and discovery.

A similar study by Kittel showed that an "Intermediate" amount of direction during discovery helped students to learn, retain, and transfer more than did "Minimum" or "Maximum" guidance.[62] Wittrock, using codes, had demonstrated that giving rules was more effective than not giving rules if retention and transfer were criteria.[63] In 1958, Haslerud and Meyers used codes to show that independently derived principles are more transferable than principles given.[64] On the other hand, Kersh identified a superiority of transfer and of motivating power for a guided discovery method of teaching.[65,66] Using an arithmetic task, as was used in the Kersh experiments, Gagne and Brown

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[61] Swenson, Anderson and Stacey, Learning Theory in School Situations (Minneapolis: University of Minnesota Press, 1949), cited in Craig, loc. cit.

[62] J. E. Kittel, "An Experimental Study of the Effect of External Direction on the Transfer and Retention of Principles," Journal of Educational Psychology, 48:391, 1957.

[63] Wittrock, op. cit., pp. 183-190.

[64] G. M. Haslerud and Shirley Meyers, "The Transfer Value of Given and Independently Derived Principles," Journal of Educational Psychology, 49:6:293, 1958.

[65] Bert Y. Kersh, "The Adequacy of Meaning as an Explanation for the Superiority of Learning by Independent Discovery," Journal of Educational Psychology, 49:5:282, 1958.

[66] Bert Y. Kersh, "The Motivating Effect of Learning by Directed Discovery," Journal of Educational Psychology, 53:2:65, 1962.

designed three auto-instructional programs analogous to the three modes of teaching already identified.[67] The Discovery Group proved superior in transfer, followed by the Guided Discovery Group, and the Directed Group. In 1961, Ray used as a learning task the use of a micrometer.[68] Comparing a group given directed and detailed instruction to one called a directed discovery group, and looking for interaction between IQ and method he found that neither group was superior in learning to use the device, and no difference showed after one week. However, after six weeks, the discovery group scored higher on a test of retention. No interactions were found between method and intelligence.

At least one attempt has been made to correlate the results of the many studies and varied findings from them. Kersh and Wittrock analyzed subject tasks without regard for the labels attached by the investigators themselves.[69] On the basis of this analysis, it is shown that guided discovery is superior for learning, retention, and transfer. However, in view of the fact that these authors commit themselves to this stand at several instances, some question about these results is still in order. Oliver and Shaver have presented a more reasonable conclusion.[70] In surveying studies on teacher behavior they reason that

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[67] Robert M. Gagne and L. T. Brown, "Some Factors in the Programming of Conceptual Learning," Journal of Experimental Psychology, 62:313, 1961.

[68] W. E. Ray, "Pupil Discovery Vs. Direct Instruction," Journal of Experimental Education, 29:3:271, March, 1961.

[69] Kersh and Wittrock, op. cit.

[70] Donald W. Oliver and James P. Shaver, The Analysis of Public Controversy: A Study in Citizenship Education, U.S. Office of Education Cooperative Research Project 8145 (Cambridge, Mass.: Harvard Graduate School of Education, Harvard University, 1962), Vol. 2, Chapter 12, pp. 1-3.

at the base of all the labels used one finds the bi-polar paradigm classically referred to as authoritarian versus democratic. It is the naivety of this model which precludes significant findings.

Set and Aspiration

A novel teaching situation can prove difficult for a class of students merely because of the confrontation with novelty. Because of the set established by years of experience in an almost totally expository classroom environment, a presentation of a lesson in the hypothetical mode would be perhaps what Thelen refers to as a violation of expectations.[71] Such sets, or dominant tendencies to behave in a particular manner, could well be a problem in any school experiment.

But psychologists and educators are well aware that student behavior can be manipulated by instructions. Such induced mental sets have been the concern of a great many experiments. Maier pointed out the necessity of directional set if insightful behavior is to result from a problem situation.[72] This conclusion was reached as a result of studies involving the now famous pendulum problem. Weaver and Madden repeated essential parts of the Maier experiment.[73] In their study, a comparison was made of a group given only relevant past experience and a

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[71]Herbert A. Thelen, "The Educative Classroom: A Model," R. Wardhaugh and J. W. G. Ivany, Educational Change: Problems and Prospects (papers delivered at the 1964 Conference on the Canadian High School, Department of Secondary Education, University of Alberta, Edmonton, 1964), p. 41.

[72]Norman R. F. Maier, "Reasoning in Humans. I. On Direction," Journal of Comparative Psychology, 10:115, 1930.

[73]H. E. Weaver and E. H. Madden, "Direction in Problem Solving," Journal of Psychology, 27:331, 1949.

group given relevant past experience plus a clue which was to serve as a direction between it and the problem. Direction seemed to have no effect. The researchers pointed out that Maier may have neglected non-specific set (learning to learn), in the form of searching habits which could be transferred without direction.

Another classic among experiments on set was conducted by Luchins using the problems of the water jar variety.[74] After a series of tasks, each solvable by a formula, subjects received more problems solvable by the same formula or by a more direct method (and more obvious method to persons not given the previous problems). Among the experimental group (given the training problems), 83 per cent made set responses. Only 0.6 per cent of the control group showed set. Reed further showed that even when the concepts are very simple, the prior set of the subject makes a significant difference in his ability to learn.[75]

More recently, Keislar conducted four experiments based on Skinnerian principles, to show that neutral stimuli could be conditioned to have cue properties usable in new situations for producing problem-solving activity, for indicating to the subject when to learn, and for designating what to learn.[76] Keislar offers the explanation that variations in subjects' learning from common experiences depends upon learning

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[74] A. S. Luchins, "Classroom Experiments on Mental Set," American Journal of Psychology, 59:295, 1946.

[75] H. B. Reed, "Factors Influencing the Learning and Retention of Concepts: I. The Influence of Set," Journal of Experimental Psychology, 36:71, 1946.

[76] Evan R. Keislar, "A Descriptive Approach to Classroom Motivation," Journal of Teacher Education, 11:310, 1960.

sets developed through prior histories of different programs of reinforcement.

Bruner, too, was concerned with set when he argued against heavy reliance by pupils on external rewards, such as teacher or parental approval, in the process of discovery.[77] He claimed that these develop conforming and rote behavior inhibiting autonomous motivation.

Closely related to set as it applies to the present experiment is the concept of level of aspiration. Bruner identifies one feature of aspiration which may have significance in this respect, that is the problem of the degree of understanding which a student seeks to achieve, whether it is "knowing" the concept behaviorally or at a verbal level. Aspiration level could very well extinguish differences in achievement between experimental and control groups due to the method of teaching.[78] Failure of closed circuit television experiments, at Pennsylvania State University and at the University of Wisconsin, to differentiate between methods used has led Fritz to hypothesize a "compensatory effort" on the part of students in both control and experimental groups.[79] As a result of his feeling of competence due to teaching input the student is assumed to exert only that amount of effort required to achieve his

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[77]Jerome S. Bruner, "The Act of Discovery," Harvard Educational Review, 31:26, Winter, 1961.

[78]Jerome S. Bruner, The Process of Education (Cambridge, Mass.: Harvard University Press, 1961), pp. 29-30.

[79]J. O. Fritz, The Effect on Instruction of the Complementary Use of Audio Visual Media with Modified Patterns in the Use of Teaching Staff, U.S. Office of Education Title VII Project Number 399 (Chicago: University of Chicago, 1963), p. 7.

particular level of aspiration. Thus, the effect of the different methods is to reduce the amount of effort which the student senses to be required, the ultimate result being the usual "no significant difference" between methods of instruction.

III. ANALYSIS OF CLASSROOM INTERACTION

For many years researchers have been aware of the potency of the analysis of teacher-pupil interaction for the purposes of measuring outcomes of experiments. Yet, for a variety of reasons, few studies include classroom observation as a variable of concern. In a comprehensive review of the studies that have taken cognizance of the power of interaction analysis, Medley and Mitzel point to the expense of such observation in terms of time and money, the concern of teachers and administrators for such invasions of privacy, the atypical character of the observed scene if it is to represent the unobserved situation, and the fact that past attempts at observation have added little to our knowledge.[80] A less comprehensive but more penetrating review of the logical implications of recent attempts at interaction analysis has been undertaken by Oliver and Shaver.[81]

All of the recent attempts are modifications of a system of process interaction analysis introduced in 1948 by Bales as an instrument

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[80]Donald M. Medley and Harold E. Mitzel, "Measuring Classroom Behavior by Systematic Observation," N. L. Gage (ed.), Handbook of Research on Teaching (Chicago: Rand McNally & Company, 1963), p. 247.

[81]Oliver and Shaver, op. cit., Volume 2, Chapter 12.

for the study of small group behavior.[82] In essence, the analysis is made by one or more observers using one or more techniques of recording the teacher-pupil interaction. The records are analyzed in terms of a system of categories generated from a theory relating to a model of teacher-pupil interaction. Very little improvement in recording techniques has been made since Bales' study except in mechanical quality. The variation from study to study is in the system of categories used in analysis.

IV. SUMMARY

Ferment in the field of science education has been caused by the failure of traditional techniques to reach desired teaching goals. Among many suggestions for improvement, the teaching of science as inquiry seems to be most closely related to certain developments taking place in the field of the psychology of learning. An information processing model of thinking appears invaluable as a guide to inquiry teaching techniques and as an instrument for the analysis of classroom interaction. An attempt should be made to define expository and hypothetical modes of teaching in terms of such a model.

Past studies which have dealt with the "discovery" of principles have generally used as criteria the retention and transfer of learning. The theory of inquiry teaching places great emphasis upon the process of learning. Studies are needed to inspect aspects of this process in the

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[82]Robert F. Bales, Interaction Process Analysis: A Method for the Study of Small Groups (Cambridge, Mass.: Addison-Wesley Press, 1950).

school situation before practical directives can be derived. Such studies would have to take cognizance of mental set and aspiration as relevant variables.

CHAPTER III

METHODS AND MATERIALS

I. THE SAMPLE POPULATION

Grade Level

Recent studies of thinking using the verbal medium have been directed at the grade 5 and 6 levels.[1,2] The theoretical framework for such choices had been established by Jean Piaget who has claimed that the onset of formal operations, the most abstract form of human thought, occurs around the age corresponding to the late elementary years.[3,4] These studies have yielded somewhat disappointing results. One conclusion which might be drawn is that although formal operations might develop earlier, the verbal skills required to communicate such abstract thought patterns might well be a later development. It was decided, therefore, to conduct this study at the grade eight level with a view to shedding light on such a postulate.

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[1]David P. Butts, "The Degree to Which Children Conceptualize from Science Experiences," Journal of Research in Science Teaching, 1:135-143, June, 1963.

[2]J. Richard Suchman, The Elementary School Training Program in Scientific Inquiry (Urbana, Ill.: College of Education, University of Illinois, 1962), p. 1.

[3]Bärbel Inhelder and Jean Piaget, The Growth of Logical Thinking From Childhood to Adolescence, Trans. Anne Parsons and Stanley Milgram (Toronto: Basic Books, Inc., 1958), pp. 105-106.

[4]J. McV. Hunt, Intelligence and Experience (New York: The Ronald Press Company, 1961), pp. 230-231.

Selection and Placement of the Sample

Using a table of random numbers a selection of twelve classes was made from the one hundred sixty-six grade eight rooms in the Edmonton, Alberta, Public School System. Classes were assigned, one at a time, to each of four groups (A, B, C, and D) in order of random selection. The total number of students involved was three hundred fifty-four. Table I shows the distribution of students by sex, class and experimental group.

II. TREATMENT PROCEDURES

Description of Four Treatments

In all classes the initial supply of information relevant to a problem was controlled through the use of sixteen millimeter sound film. The differences among groups related to the particular amount and kind of information input. As suggested in a study by Schippers, the science problems were viewed as composites of three phases: presentation of a situation, identification of the problem, and problem solution.[5] Three basic methods of instruction were defined in terms of these phases and used in the study.

Treatment A. The expository mode provided a control for the inquiry groups. It included components of all three phases identified by Schippers. The teacher, in such a situation, presents selected data

[5] John Vernon Schippers, "An Investigation of the Problem Method of Instruction in Sixth Grade Science Classes" (unpublished Ph.D. dissertation, State University of Iowa, 1962), p. 3.

TABLE I

DISTRIBUTION OF STUDENTS

Group	A			B			C			D		
Class	01	02	03	04	05	06	07	08	09	10	11	12
Boys N	21	21	11	14	9	11	24	17	17	12	13	13
Girls N	7	11	20	13	15	21	16	17	13	18	17	13
Class N	28	32	31	27	24	32	30	34	30	30	30	26
Group N		91			83			94			86	
Total N							354					

and indicates to the student the appropriate processing of it. For this treatment a problem film included a description of the problem situation, a verbal formulation of the problem, and a solution reached by examination of the relevant data in terms of a sound hypothesis.

Treatment B. An intermediate mode included components of situation and problem identification phases. The data processing problem presented to the student was increased in that only a focus for the relevant data was provided in the formulation of the problem. The sound pictures used with the "B" group contained descriptions of the problem situation and concluded with the problem being verbally formulated. At the end of each film, the students in this group were responsible for hypothesis generation and testing, the conclusion being left entirely to the student.

Treatment C. The hypothetical mode represented the extreme experimental group of the study. Problem situations, on film, were presented without the aid of verbal description. Autonomous inquiring activity was required to formulate the problems, generate hypotheses, test these, and to arrive at some conclusion.

Treatment D. A fourth category was given the same treatment as group C. However, classes assigned to this category were given an extra lesson, not recorded on film, in order to provide the students with practice in identifying various kinds of questions which could be asked regarding a problem, and in comparing the power of the different types. Treatment D was given in an attempt to offset the expected problem of set

and to investigate the feasibility of introducing inquiry techniques into an ongoing school situation without a great deal of retraining.

A common procedure was used in all classes after the initial input of information. Students were instructed that their inquiry should take the form of questions directed at the teacher and structured so as to be answerable as far as possible by "yes" or "no." This was to insure that the inquiry would be of comparable form among the classes and that the inquiry be autonomous. During this part of each lesson, tape recordings were made of the classroom activity thus providing a record of attempts at inquiry under differential information input.

Each class was subjected to six filmed episodes over periods ranging from two to three weeks. Prior to the instructional period in which the film was used the classroom teachers discussed its content with the investigator.

Variation From Initial Design

To facilitate administration of the experimental procedures it was necessary to deviate from the original intent in certain instances. It had been hoped that the classroom science teacher would conduct the inquiry sessions after the filmed presentations. In two classes this was not accomplished and the investigator conducted the sessions. This, perhaps, contributes an amount of contamination to the data. More important, because students were not known to the investigator at the beginning, no record of individual participation was obtained for these two classes. For this reason, in the analysis of individual inquiry these classes (Class 01, Group A and Class 04, Group B--See Table I) were

omitted. At the level of class and group analysis, however, all twelve classes were involved.

Testing Procedures

At the beginning of the experimental period in each class, students were examined on the STEP General Science Test (form 3A), on both parts of the Q-Sort Instrument, and on a test of achievement related to the topics to be considered in the experimental films. At the end of the experiment, all of these tests except the STEP General Science Test were readministered as post-tests to measure changes. Each of these instruments is discussed below.

III. THE FILMED EPISODES

Selection of Topics

In choosing topics for the problem films a number of considerations was important. An attempt was made to relate the concepts involved to the present stage of development of the student. At the same time, to provide maximum likelihood that the problems would be novel to the students, the particular content was not that usually contained in a grade eight science course. Another feature of selection, previously mentioned, was the disequilibrium created by the visual presentation of the problem. All six problems were from the general area of physics. Each was tried for suitability in a grade eight class not otherwise connected with the experiment and it was during this phase that mechanical details of classroom recording were worked out. Appendix A lists the films by title, in order of presentation to each class, and the major

relational concepts underlying each and therefore subject to the inquiry.

Preparation of Films

The films used in the study were originally prepared for videotape recording using the television facilities of the A-V Media Center of the University of Alberta, Edmonton. The final product was a kinescope prepared from the video record. Each problem film was of approximately six minutes duration.

IV. TESTING INSTRUMENTS

S.T.E.P. Science Test

Characteristics of the Sequential Tests of Educational Progress (S.T.E.P.) in most subject areas prepared by Educational Testing Services Inc., have been well documented.[6,7] For this study the General Science Test, form 3A, for junior high school grades was used as a control and reference variable. The test is intended to measure scientific knowledge and aptitude. This particular test was chosen because of a suspected high loading on a verbal factor which was felt desirable as a control for verbal inquiry.[8] In addition it correlates rather highly with measures of intelligence. Reliability estimates as published in

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[6]O. K. Buros (ed.), The Fifth Mental Measurements Yearbook (Highland Park, N.J.: The Gryphon Press, 1959), pp. 802-805.

[7]Anne Anastasi, Psychological Testing (New York: Macmillan Company, 1961), pp. 447-448.

[8]Robert M. Travers, "Sequential Tests of Educational Progress," The Fifth Mental Measurements Yearbook, O. K. Buros (ed.), op. cit., p. 805.

the S.T.E.P. Technical Report are reproduced in Table II.[9]

Q-Sort Instrument

The Q-Sort Instrument used was a modification of the one developed for a study by Fritz.[10] The instrument is intended to record the student's perception of his role in the classroom with respect to twenty-eight teaching-learning tasks, based partly on Bloom's Taxonomy of Educational Objectives.[11] The tasks are subdivided, during analysis, into three categories representing tasks of evaluation, inquiry, and tasks related to learning experiences. Each task is printed on a three by five index card, twenty-eight cards making the full "deck" which each student sorts. The sorting is into four groups representing tasks which are the students' responsibility, the students' and teacher's responsibility, the teacher's responsibility, and neither of these. In scoring, tasks sorted by the student into the students' responsibility group are weighted four, those sorted into the group corresponding to students' and teacher's responsibility are weighted three, the teacher's responsibility, two, and neither of these, one.

At each administration of the Q-Sort, the cards were sorted by the students twice according to different instructions. On the first

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[9] STEP Technical Report (Princeton, N.J.: Educational Testing Services, Cooperative Testing Division, 1957).

[10] John O. Fritz, The Effect on Instruction of the Complementary Use of Audio-Visual Media With Modified Patterns in the Use of Teaching Staff (U.S. Office of Education Title VII Project Number 399, Chicago: University of Chicago, September, 1963), pp. 32-33.

[11] Benjamin S. Bloom et al., Taxonomy of Educational Objectives: The Classification of Educational Goals: Handbook I, Cognitive Domain (New York: Longmans, Green & Company, Inc., 1956).

TABLE II

RELIABILITY ESTIMATES OF TESTS[a]

Test	Reliability	Highest Correlation with Other Variables
STEP Science Test	.81 K	.503 (Post Achievement)
Achievement Test	.725 .773K	.510 (Pre-Post Achievement)
You-Sort	.651	.706 (You-Sort evaluation)
Sub-scores evaluation	.354	.706 (You-Sort)
inquiry	.388	.694 (You-Sort)
learning	.513	.681 (You-Sort)
Teacher Sort	.555	.478 (Pre-Post Sort)
Sub-scores evaluation	.421	.860 (Teacher-Sort inquiry)
inquiry	.186	.881 (Teacher-Sort learning)
learning	.592	.881 (Teacher-Sort inquiry)

[a]Test-Retest over two weeks except where postscripted by K which indicates a Kuder-Richardson Formula 20 calculation.

occasion the student was instructed to sort the tasks according to what he, himself, felt ought to be the case. This part of the test is hereafter referred to as the <u>You</u>-<u>Sort</u>. The second sorting was done according to instructions to sort the tasks as the student thought his science teacher felt ought to be the case. This part is hereafter referred to as the <u>Teacher</u>-<u>Sort</u>.

The modifications from the original instrument were made partly in cognizance of the verbal difficulty of a test designed for high school seniors and being used in grade eight. In addition, some items of the original were specific to the study for which it was designed. These were replaced by items similarly specific to the present study. The modified Q-Sort Instrument is reproduced with instructions for use in Appendix B.

The reliability of the Q-Sort was checked in two grade eight classes not otherwise connected with the experiment. A test-retest method was used over a two-week interval. The results are reported in Table II.

<u>Achievement</u> <u>Test</u>

The major purpose of this test was to provide a control based on a conventional measure of progress even though this study was premised on the belief that other, perhaps more important, measures of progress must be made. But it should be shown whether the inquiry mode (less efficient in transmitting information) prohibits learning of concepts and principles more than does conventional exposition. The test was composed of twenty-four items of multiple choice format with

four choices. Students were encouraged to guess rather than omit an answer. The construction of the test was guided by the National Science Teachers' Association's booklet, Let's Build Quality Into Our Science Tests.[12] Reliability estimates were based on a test-retest over a period of two weeks in three grade eight classrooms. In addition a Kuder-Richardson Formula 20 r was computed from the pre-test data in the twelve experimental classrooms. These coefficients are reported in Table II. The Achievement Test appears in Appendix B.

Suchman Question Analysis

The twelve categories into which Suchman places student questions were listed in Chapter II. Using this scheme the fluency of questioning (total number of questions initiated) and the frequency of use of each category can be calculated. The system ignores contribution by the teacher, but it was the intention of this experiment to control the differing effect of teachers from class to class. Reliability of use of the scheme for the data from this study was controlled by having two competent judges check initial categorizations made by the investigator until a high degree of consensus was reached. An elaboration of the categories with examples taken from this experiment is contained in Chapter IV. A sample of coded transcribed inquiry obtained following the presentation of one of the problem films appears in Appendix C.

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[12]Clarence H. Nelson, Let's Build Quality Into Our Science Tests (Washington: National Science Teacher's Association, 1958).

V. STATISTICAL DESIGN

Multiple Linear Regression

The technique of multiple linear regression has been for some time recognized as a powerful tool for investigating relationships between a set of independent variables (predictors) and a dependent variable (criterion).[13] Its use has been limited due to a near necessity for high speed computing equipment. Meanwhile, the less powerful techniques of variance and covariance analysis (limited cases of multiple regression) have played major roles in educational research.

The basic assumption of multiple linear regression is that between a set of n predictors X_i $i = 1$ to n and a criterion Y there exists a linear relationship of the form:[14,15]

$$3.1 \qquad Y = W_1X_1 + W_2X_2 + \ldots. + W_nX_n + W_{n+1}$$

where the W_i are weighted coefficients. In use, the set W_i is selected so as to minimize the error sum of squares (ESS) between the thus predicted criterion, $\hat{Y}_1$, and the measured values of Y. Thus we get:

$$3.1a \qquad \hat{Y}_1 = W_1X_1 + W_2X_2 + \ldots. + W_nX_n + W_{n+1}$$

The error sum of squares is calculated over the N individuals for whom scores are available, as follows:

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[13]Joe H. Ward, Jr.,"Multiple Linear Regression Models," _Computer Applications in the Behavioral Sciences_, Harold Borko (ed.) (Englewood Cliffs, N.J.: Prentice-Hall, Inc.,1962), pp. 205-207.

[14]_Ibid_., pp. 207-236.

[15]Robert A. Bottenberg and Joe H. Ward, Jr., _Applied Multiple Linear Regression_, Clearinghouse for Federal Scientific and Technical Information. U.S. Department of Commerce, Technical Documentary Report PRL-TDR-63-6 (Washington: Government Printing Office, 1963).

$$3.2 \quad ESS = \sum_{i=1}^{N} (Y_i - Y_{1_i})^2$$

Data may be either categorical or continuous. For categorical data the predictor $X_i = 1$ if the subject is a member of the category, otherwise $X_i = 0$.

The observed product-moment correlation R_1 between Y and $\hat{Y}_1$ is a measure of goodness of fit between observed and predicted values of the criterion. Its square, called the squared multiple correlation (RSQ), represents the proportion of the variance of the criterion accounted for by 3.1a, the linear equation predicting $\hat{Y}_1$, and called, say, Model 1.

To investigate the effect of a particular variable <u>in the presence of the others</u>, say X_3, a new model, Model 2, is written such that:

$$3.3 \quad \hat{Y}_2 = W_1X_1 + W_2X_2 + W_4X_4 + \ldots, + W_nX_n + W_{n+1}$$

Equation 3.1a is referred to as the full model, using all the possible predictor information for the study. This equation, 3.3, is referred to as the restricted model since it restricts variable X_3. This new model leads to a squared multiple correlation $(R_2)^2$ which will be less than or equal to $(R_1)^2$. In a similar manner, all n predictor variables of an experiment can be investigated leading to the set $(R_j)^2$ $j = 2$ to $n+1$.

To test the significance of the contribution of any one variable X_i in the presence of the others an F ratio (under certain assumptions) can be formed. The degrees of freedom (df_j) for Model J are dependent upon the number of independent predictor vectors (P_j) in the model. The appropriate formula for F is:

$$3.4 \quad F = \frac{(R_1^{\,2} - R_j^{\,2}) \,/\, df_1}{(\,1 - R_1^{\,2}) \,/\, df_2}$$

where: R_1 = RSQ of the full model

R_j = RSQ of the appropriate restricted model

$df_1 = P_1 - P_j$

$df_2 = N - P_j$

P_j = number of independent weights in model j including W_{n+1}.

In analogous fashion, contributions of linear and curvilinear relationships (or interactions) among two or more variables can be studied merely by generating the appropriate interaction vector. This new vector is then used as a predictor variable in a new model.

At the University of Alberta, Edmonton, the IBM 7040 computing facility allows use of a simple and convenient program called PERSUB to do the necessary computation.[16] Throughout the analysis in this study this program was used.

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[16] _Ibid_.

CHAPTER IV

RESULTS AND ANALYSIS

It had not been planned to separate the analyses of test data and of verbal interaction patterns, although the possibility that this procedure might be required was recognized. Flanders,[1] and Taba,[2] both, had found it necessary to make non-parametric investigations of data based on the categorization of classroom dialogue. The Suchman type of analysis, however, had been used by its author in a variance analysis.[3] Realizing that the assumption regarding the independence of fluency scores (based on number of questions asked) was not rigorous, it was, however, proposed to undertake a parametric analysis. But the frequency distribution of such scores prevented full use of this approach. The distribution, shown in Figure 2, varied greatly from normality. A number of transformations were attempted but to no avail. Such a distribution is not surprising since it represents the usual pattern of voluntary verbal participation in classrooms. It is apparent, then, that the Suchman scheme of question analysis, when used as in this

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[1]E. J. Amidon and N. A. Flanders, The Role of the Teacher in the Classroom (Minneapolis: Paul S. Amidon and Associates, 1963).

[2]Hilda Taba, Samuel Levine, and Freeman F. Elzey, Thinking In Elementary School Children, U. S. Office of Education, Cooperative Research Project No. 1574 (San Francisco: San Francisco State College, 1964).

[3]J. Richard Suchman, The Elementary School Training Program in Scientific Inquiry, U. S. Office of Education Title VII Research Project Number 216 (Urbana, Illinois: College of Education, University of Illinois, 1962), pp. 51-74.

It has not been claimed [illegible] use of verbal interaction [illegible], although [illegible] procedure [illegible] Flanders,[1] and [illegible], had found it necessary to [illegible] based on the [illegible] of [illegible]. The [illegible] type of analysis, however, has been used [illegible] Realizing that the [illegible] scores (based on [illegible] however, proposed to [illegible] distribution of [illegible]. The distribution, shown in Figure [illegible] number of [illegible] were [illegible]. [illegible] tribution is not [illegible] voluntary verbal participation [illegible]. It is apparent, then, that the [illegible]

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[1]N. A. Flanders and [illegible]

[2][illegible] Research Project No. [illegible] 1964).

[3][illegible] Number 216 [illegible] Illinois, 1962, pp. [illegible].

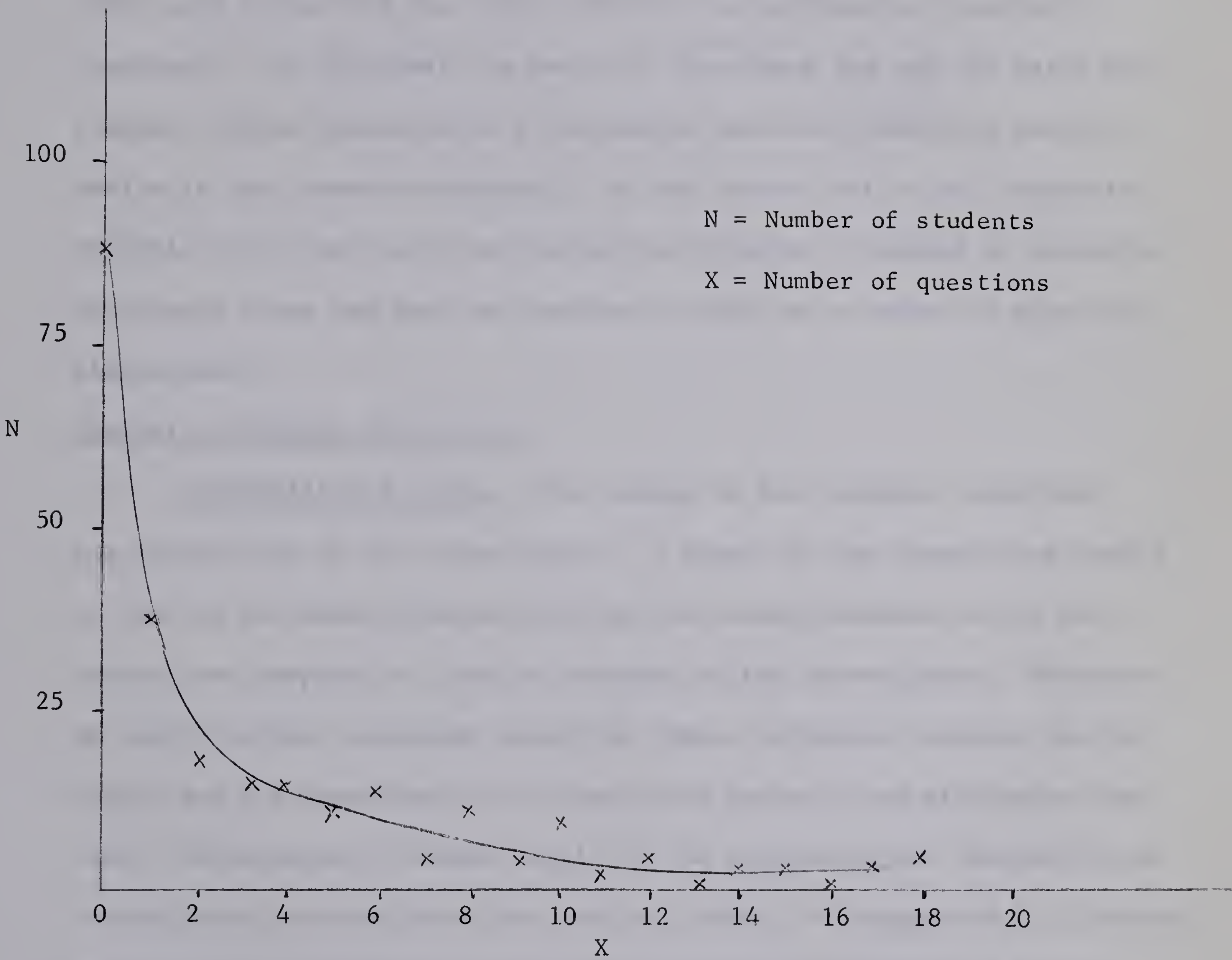

Figure 2

Frequency Distribution For Fluency of Verbal Inquiry

experiment, is not appropriate for variance analysis using confidence intervals defined by the distribution of F.

For these reasons the analysis is presented in two parts. The first part deals with the verbal interaction patterns in relation to treatments. It considers the parts of hypotheses one and two using contingency tables supported by a regression equation predicting participation in each question category. In the second part a full regression analysis of pre and post test scores and referent variables is presented. Hypotheses three and four are explored as well as a number of minor considerations.

Analysis of Verbal Interaction

Reliability of coding. The coding of the students' questions was carried out by the investigator. A sample of the transcribed record of inquiry was coded independently by two faculty members at the university and compared to results obtained by the investigator. There was an eighty percent agreement among the three. Agreement between the two judges and the investigator was ninety-two percent, and eighty-four percent. In addition, a random sample of the transcript was recoded by the investigator one week after the initial coding. As suggested by Flanders,[4] the Scott "pi" coefficient was used to check self reliability because this coefficient is unaffected by low frequencies, can be adapted to percentages, and is more sensitive at higher levels of reliability.

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[4]Ned A. Flanders, Teacher Influence, Pupil Attitudes and Achievement. Pre-publication manuscript of a proposed research monograph for the U.S. Office of Education, Cooperative Research Branch, 1962), p.39.

Scott's coefficient is determined by the following formula:

$$\pi = \frac{P_o - P_e}{1 - P_e},$$

where: P_o is the proportion of agreement,

P_e is the expected proportion of agreement, found by squaring the proportions of tallies in each category and summing over all categories.

The resultant "pi" and the tallies for each category appear in Table III.

The category totals appear in columns one and two for each of the attempts at classification. Columns three and four contain the percent of tallies in each category. Column five shows the differences between three and four. Column six is the square of the average percent in each category.

In the discussion that follows, all comparisons are based on a twenty minute sample of the inquiry behavior which immediately followed each of the film presentations. In a few cases the full twenty minutes was not required. This was particularly true of the group exposed to the expositional input. In the groups for whom no answer to the problem was posed, it was almost always the case that more than twenty minutes was spent asking questions. For comparability it was decided to use the twenty minute period, since in no instance was there a shorter time period available for student questioning. In the five instances of the seventy-two periods of inquiry where less than this amount of time was utilized the students themselves determined the length of the inquiry session.

TABLE III

SELF RELIABILITY IN CODING USING SCOTT PI

	col.1	col.2	col.3	col.4	col.5	col. 6
Category	A	B	A%	B%	A-B %	(Avg.%)^2
Nominal	11	11	2.8	2.82	.01	.0792
Normative	1	1	.26	.26	.00	.0007
Descriptive	110	114	28.06	29.23	1.17	8.2054
Comparative	53	51	13.52	13.08	.44	1.7689
Structural	24	24	6.12	6.15	.03	.3764
Properties	37	33	9.44	8.46	2.15	.8010
Diffuse	32	30	8.16	7.69	.47	.6281
Directed	103	106	26.28	27.18	.90	7.1449
Elimination	2	2	.51	.51	.00	.0026
Substitution	6	7	1.53	1.80	.27	.0277
Addition	5	4	1.28	1.03	.25	.0133
Concrete Conceptual	8	7	2.04	1.08	.24	.0369
TOTALS	392	390			5.93	19.0851

$$\pi = \frac{P_o - P_e}{100 - P_e} = \frac{(100 - 5.93) - 19.09}{100 - 19.09} = 92.67$$

<u>Hypothesis 1.1</u> This hypothesis postulated no difference in the number of questions asked by students in different information input situations. Table IV presents the number of tallies in each category for the ten classes concerned in this part of the analysis. There was a wide range in the totals for each class, from 107 questions in classroom 3 of Group A to 397 questions in classroom 11 of Group C. Table V shows the average number of questions per class in the four groups and shows the results of a chi square test of goodness of fit assuming a rectangular distribution along the average number of questions in all ten classes. It is seen that the increase in question volume from Group A to Group D is quite significant, the degree of association between number of questions and group membership being 0.22 as measured by the contingency coefficient. It might be pointed out that the significance of the relationship is not due only to a low frequency of questioning in the A group, but also to the high rate of questioning in Group D.

It is fairly evident that we must reject the null hypothesis in recognition of differences in the number of questions elicited by the four treatments.

<u>Hypothesis 1.2</u> In order to view the results of 1.1 in perspective it is necessary to investigate the proportion of student participants in each group. This hypothesis postulated no difference in the amount of participation as a result of variable information input. Table VI indicates that a rather stable proportion of the students in a class will participate in verbal inquiry regardless of the nature of the

TABLE IV

NUMBER OF QUESTIONS PER CATEGORY BY CLASSROOM
FOR SIX PERIODS

	CLASSROOM									
	02	03	05	06	07	08	09	10	11	12
Verification	8	5	4	7	26	27	10	33	13	14
Nominal	3	4	3	7	25	15	9	33	11	14
Normative	5	1	1	0	1	12	1	0	2	0
Analytical	73	40	90	84	136	122	85	161	221	126
Descriptive	27	24	38	31	61	60	42	68	115	65
Comparative	9	11	23	24	25	37	23	40	50	27
Structural	7	1	14	7	25	12	7	29	23	11
Properties	30	4	15	22	25	133	13	24	33	23
Abstract Concep.	68	32	107	99	112	168	57	114	129	121
Diffuse	30	4	31	19	21	47	10	33	30	36
Directed	38	28	76	80	91	121	47	81	99	85
Inferential	76	27	18	1	19	5	6	10	19	7
Edlimination	12	3	3	1	2	0	0	4	4	1
Substitution	52	18	14	0	12	2	6	5	11	4
Addition	12	6	1	0	5	3	0	1	4	2
Concrete Concep.	26	3	13	7	3	3	4	9	15	3
TOTALS	251	107	232	198	296	325	162	312	397	271

TABLE V

NUMBER OF QUESTIONS PER CLASS
OBSERVED AND EXPECTED REEQUENCIES

	O	E	$\frac{(O - E)^2}{E}$
Group A	179	255	22.65
Group B	215	255	6.28
Group C	261	255	0.14
Group D	327	255	20.33

$X^2 = 49.40$, $p < .001$, $C = 0.22$

problem. Participation in the ten classrooms ranged from 51.6 per cent to 86.7 per cent with the average being just above 67 per cent. Once again a slight trend across groups indicating greater participation with decreasing input is noticed. Table VII shows that the trend is not significant in this case.

Combined with the results from above this suggests that hypothesis one regarding the quantity of the inquiry is only partly supported. While it appears true that varying information input has no effect upon the number of student participants in the verbal phase of inquiry, the increased degree of participation with decreasing input leads us to reject that part of the hypothesis concerning the number of questions elicited.

Hypothesis 2.1 The second hypothesis concerned the quality of autonomous inquiring activity elicited from the four treatment groups. In the first part it was postulated that the number of verbal functions, or question categories used would not be different. Table VIII records the number of questions in each category according to treatment group. It can be seen that while all categories were perceived as appropriate to the inquiry of all groups, a wide range in the frequency of use of each was recorded. The most frequently used specific category in Group A was the question of substitution, while in Groups B, C and D the most used type was the directed relationship. Characteristics of the various types are explored fully below.

Before proceeding cognizance should be taken of problems connected with categorization of questions. Use of a question analysis scheme such as this is, of course, prone to the problems of use of any theoretical model in an experimental situation. In most instances students' questions were not simple but contained a complex mix of thought units.

TABLE VI

NUMBER OF STUDENTS (N) AND NUMBER OF
PARTICIPANTS (P) DURING INQUIRY BY
CLASSROOM AND BY GROUP

	N	P	%
Group A	63	40	63.5
2	32	24	75.0
3	31	16	51.6
Group B	56	37	66.1
5	24	16	66.7
6	32	21	65.6
Group C	96	72	75.0
7	30	26	86.7
8	35	23	65.7
9	31	23	74.2
Group D	88	64	62.5
10	32	20	62.5
11	30	24	80.0
12	26	20	76.9

TABLE VII

PROPORTION OF PARTICIPANTS
OBSERVED AND (EXPECTED)

	Group A	Group B	Group C	Group D
Participants	40	37	72	64
	(44.3)	(39.4)	(67.5)	(61.9)
Non-Participants	23	19	24	24
	(18.7)	(16.6)	(28.5)	(26.1)

$X^2 = 3.2$, df = 3, N.S.

TABLE VIII

NUMBER AND PROPORTION OF QUESTIONS PER CATEGORY BY GROUP[a]

	A		B		C		D	
	No.	%	No.	%	No.	%	No.	%
CATEGORICAL VERIFICATION	13	3.6	11	2.6	63	8.1	60	6.1
Nominal	7	2.0	10	2.3	49	6.3	58	5.9
Normative	6	1.7	1	0.2	14	1.8	2	0.2
ANALYTICAL VERIFICATION	113	31.6[b]	174	40.5	343	43.8[b]	508	51.8[b]
Condition-Descriptive	51	14.3	69	16.1	163	20.8	248	25.3
Condition-Comparative	20	5.6	47	10.9	85	10.9	117	11.9
Structural Component	8	2.2	21	4.9	44	5.6	63	6.4
Properties Check	34	9.5	37	8.6	51	6.5	81	8.2
ABSTRACT CONCEPTUAL IMPLICATION	100	27.9	206	47.9[b]	337	43.0	364	37.1
Diffuse	34	9.5	50	11.6	78	10.0	99	10.1
Directed	66	18.4	156	36.3[c]	259	33.1[c]	265	27.0[c]
CONCRETE INFERENTIAL IMPLICATION	103	28.8	19	4.4	30	3.8	36	3.7
Elimination	15	4.2	4	0.9	2	0.3	9	0.9
Substitution	20	19.6[c]	14	3.3	20	2.6	20	2.0
Addition	18	5.0	1	0.2	8	1.0	7	0.7
CONCRETE CONCEPTUAL IMPLICATION	29	8.1	20	4.7	10	1.3	27	2.8
totals	358		430		783		980	

a Groups A, B contained 2 classrooms each while Groups C, D contained 3 for this analysis.

b Major question category used with highest frequency in the group.

c Specific question type used with highest frequency in the group.

In fact, it may be said that the usual question is more of a compound statement with an inflection added almost as an after-thought. Students appeared to have difficulty in framing questions. The category to which such a statement was assigned was chosen with regard to the major idea contained and to the answer of the teacher since only that part of the question which was answered succeeded in advancing the inquiry.

Hypothesis 2.2 This hypothesis suggested that the frequency with which the various verbal functions were used was independent of the amount of information supplied. Each of the question types was treated separately using a chi square test of association between the four treatment categories and categories determined by the frequency with which the type of question was asked. The elements in the cells were numbers of students. In each case the frequency categories which constituted the columns of the matrix were determined beforehand on the basis of results reported in Suchman's study.[5] In addition, a categorical vector recording 1 (if the student participated with the particular type of question) or 0 (if he did not) served as the criterion for a regression equation exploring qualitatively the weighting of each treatment in the presence of the STEP Science score, Pre-Achievement score, Pre-Q Sort scores and the total number of questions asked by the student.

Categorical Verification. These questions attempt to identify the objects and events of a problem by assigning them to classes. There are two main subtypes. The nominal question serves merely to identify the class. (e.g. "Was that a flashlight?"). The normative

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[5]Suchman, op. cit., pp. 66-74.

question attempts to relate the object or event to a norm for the class. (e.g. "Was that an ordinary flashlight?").

As has been illustrated in Table VIII the frequency of use of normative verification was low in all groups. As a result it was combined with nominal verification for the test of association. Table IX presents the matrix of observed and expected values and chi square. The result is insignificant. Categorical verification questions are not used by any group with a frequency significantly higher or lower than any other. Relating this result to the data contained in Figure 3 provides an interesting observation. In this diagram is shown the percentage of categorical questions asked in each group, the per cent based on the total number of questions in the group. Although there was no difference in the number of participants using these categories, the participants from groups C and D made proportionately greater use of them.

The result of the regression equation analysis tend to support the findings of the chi square test. Although statistical significance is not assumed it is found that the treatments combined contribute twenty per cent of the variance of the regression equation in the presence of the STEP Test, Achievement Test, the Q Sort scores and the number of questions asked (fluency score). Fluency, the only other major contributor, is responsible for sixty per cent of the variance. The treatment regression weights from A to D are, respectively, -.17, -.13, .04, and .00. These appear to support the data described in Figure 3 suggesting that groups A and B used this type of question category somewhat less frequently than the others.

TABLE IX

CATEGORICAL VERIFICATION
NUMBER OF PERSONS X FREQUENCY
OBSERVED AND (EXPECTED)

	frequency 0	1	2 or more
GROUP A	31	5	4
	(25.2)	(8.5)	(6.4)
GROUP B	28	7	2
	(23.3)	(7.8)	(5.9)
GROUP C	38	18	16
	(45.3)	15.2)	(11.5)
GROUP D	37	15	12
	(40.3)	(13.5)	(10.2)

$X^2 = 11.49$, $df = 6$, N.S.

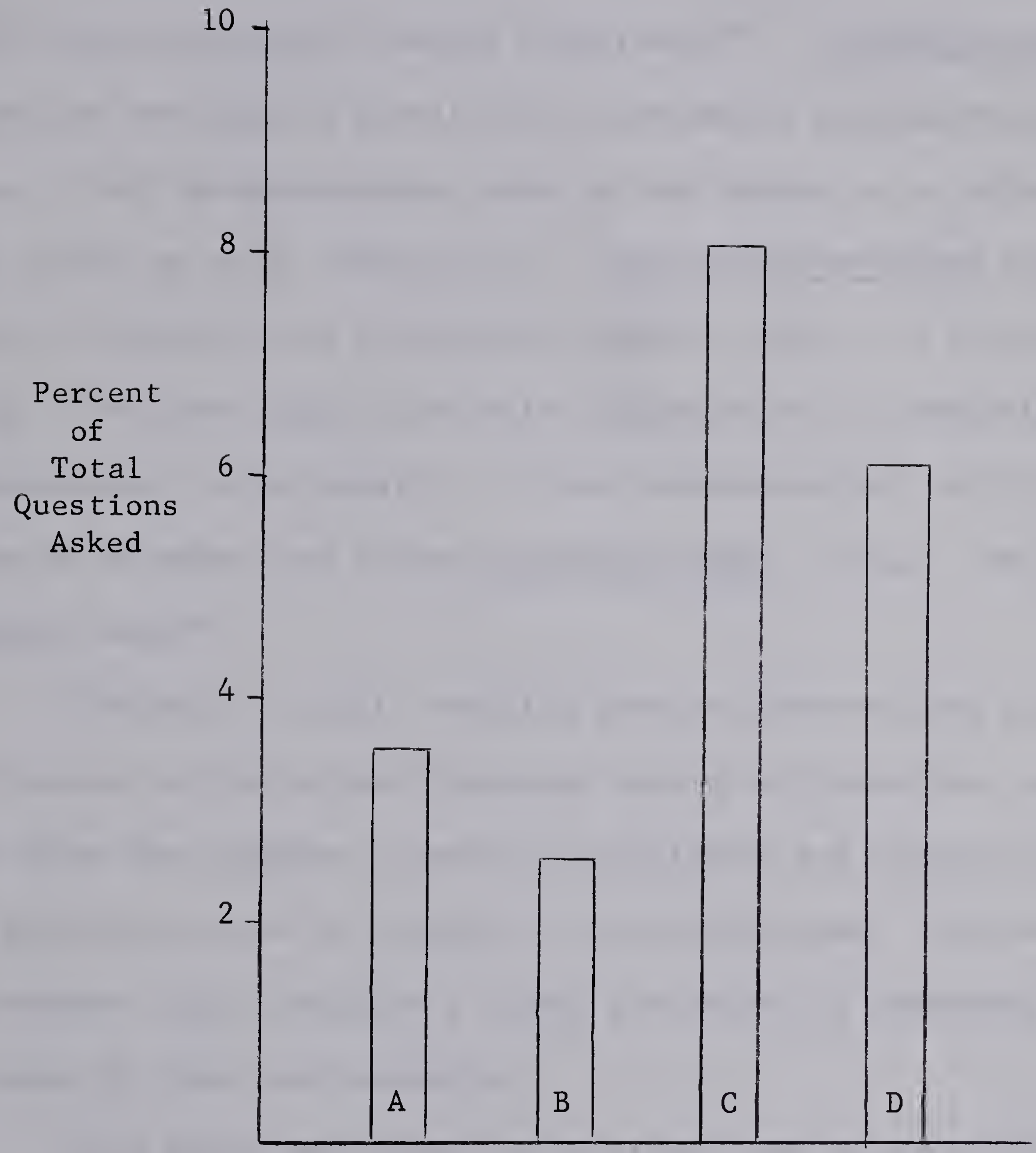

Figure 3

Percent of Questions in the Categorical Verification Category for the Four Groups

Analytical verification. Subsumed by this heading are four types of questions. Condition-descriptive refers to that type of question used to identify specific quantitative or qualitative conditions. (e.g. "Was that electroscope charged negatively?"). Condition-comparative questions are used to specify the relationship between two conditions. (e.g. "Did the electroscope have as much charge on it after the light was turned on as it had before?"). Structural-component questions are used to determine the relationship between parts of a structural whole. (e.g. "Was that copper wire with insulation on it connecting the electroscope to the metal?"). Those questions which verify the properties of an object are called Properties check. (e.g. "Do light rays contain heat?").

Tables X, XI, XII, and XIII show the observed and expected numbers of persons at the various frequency levels for these four subtypes. For the first two subtypes, condition-descriptive and condition-comparative, no significance can be attached to the differences. Reference to Figure 4, however, again suggests a higher proportion of responses from inquirers in each of these two categories.

Once again the regression equation lends support to the results of the contingency tables. For both the condition-descriptive and condition-comparative categories of questions the four treatments together account for twenty per cent of the variance as compared to seventy percent attributable to fluency. The regression weights for treatments A to D, respectively, were; for condition-descriptive, .01, -.09, .00 and .13, and for condition-comparative, -.20, .00, -.02, and .01. From this one might conclude that any trend towards greater use of these types of questions would seem to favor the D group particularly.

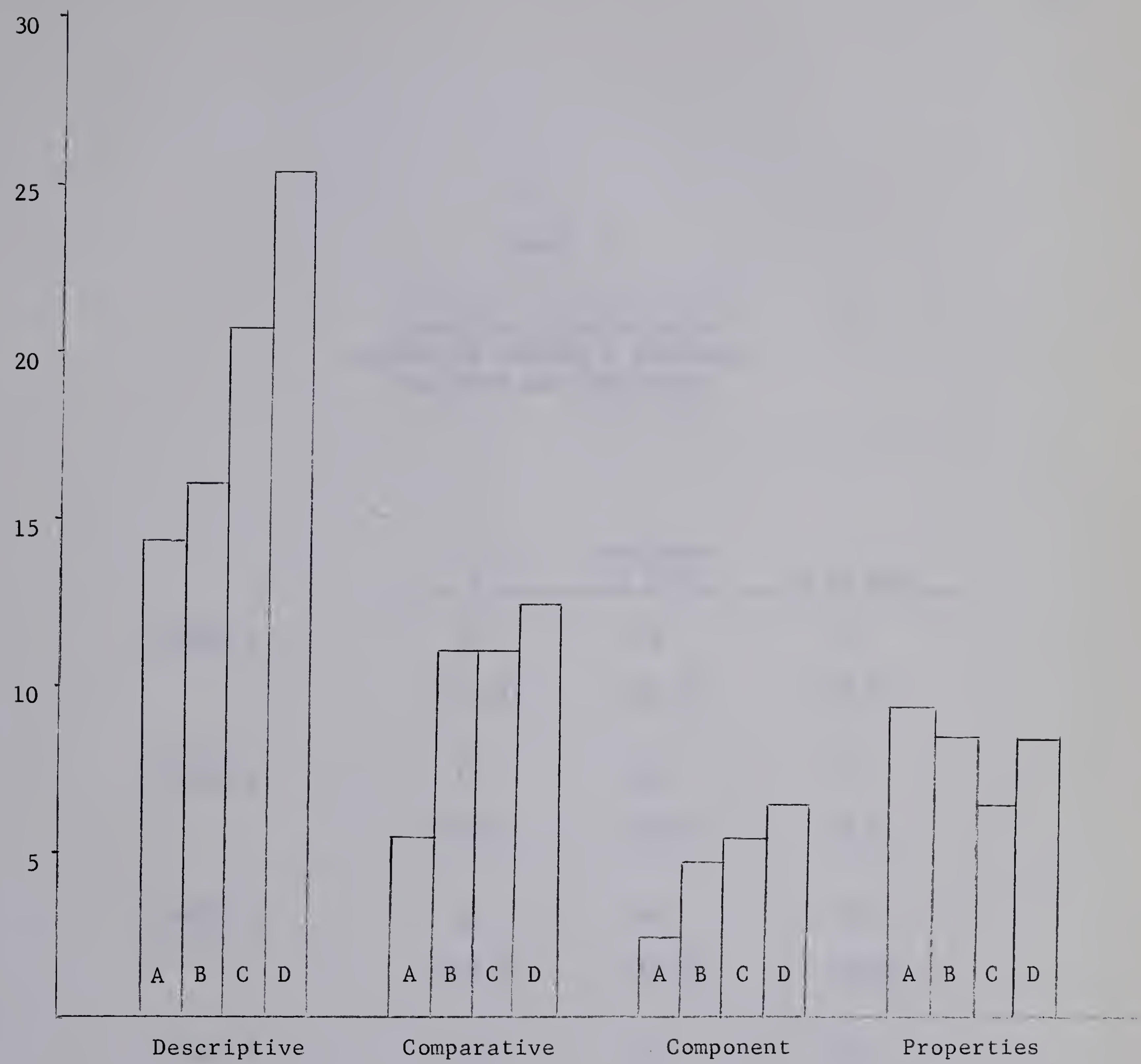

Figure 4

Percent of Questions in the Sub-categories of Analytical Verification For the Four Groups

TABLE X

CONDITION - DESCRIPTIVE
NUMBER OF PERSONS X FREQUENCY
OBSERVED AND (EXPECTED)

	frequency 0	1 - 3	4 or more
GROUP A	21	13	6
	(13.5)	(18.2)	(12.0)
GROUP B	13	18	6
	(12.5)	(16.9)	(7.6)
GROUP C	23	34	15
	(24.3)	(32.8)	(14.9)
GROUP D	15	32	17
	(21.6)	(29.2)	(13.2)

$X^2 = 12.6$, df $= 6$, N.S.

TABLE XI

CONDITION - COMPARATIVE
NUMBER OF PERSONS X FREQUENCY
OBSERVED AND (EXPECTED)

	frequency 0	1 - 2	3 or more
GROUP A	29	9	2
	(21.4)	(11.8)	(6.8)
GROUP B	18	13	6
	(19.8)	(10.9)	(6.3)
GROUP C	39	21	12
	(38.5)	(21.3)	(12.2)
GROUP D	28	20	16
	(34.4)	(18.9)	(10.8)

$X^2 = 10.98$, df = 6, N.S.

TABLE XII

STRUCTURAL - COMPONENT
NUMBER OF PERSONS X FREQUENCY
OBSERVED AND (EXPECTED)

	frequency 0	frequency 1 or more
GROUP A	34	6
	(26.7)	(13.3)
GROUP B	27	10
	(24.7)	(12.3)
GROUP C	43	29
	(48.0)	(24.0)
GROUP D	38	26
	(42.7)	(21.3)

$X^2 = 9.8$, df = 3, p = .02, C = .21

TABLE XIII

PROPERTIES CHECK
NUMBER OF PERSONS X FREQUENCY
OBSERVED AND (EXPECTED)

	frequency	
	0	1 or more
GROUP A	29	11
	(21.6)	(18.4)
GROUP B	17	20
	(20.0)	(17.0)
GROUP C	43	29
	(38.9)	(33.1)
GROUP D	26	38
	(34.6)	(29.5)

$X^2 = 11.63$, $df = 3$, p $.01$, $C = .23$

The structural component and properties check type of questions were used to a significantly different amount across groups. The number of persons using both categories, as shown in Tables XII and XIII, was higher than expected in the inquiry groups and lower in the expositional group. This result seems to be supported by the regression equations calculated for these categories. For the structural component category only four per cent of the accountable variance is predicted by treatments as opposed to seventy-seven per cent by the fluency score. However, the regression weights for treatments A to D were -.15, -.07, .00, and .00, indicating, perhaps, some support for the result of the chi square test. Contributions from other variables were very small.

The four treatments predicted twenty-one per cent of the accountable variance for the properties check category. This may be compared to sixty-five percent attributable to fluency and a very low range of contributions from the other scores. The regression weights for A to D ranged from .03 to .22, progressively, again suggesting support for the chi square analysis.

Abstract-conceptual Implication. In this category is recorded the attempts of the inquirer to hypothesize relationships among variables. Although the scale conceives of two types, the diffuse and the directed relationship, it is extremely difficult to separate the two using empirical data. Most of the relationships specified by grade eight students are quite vague. Even if there is a directed relationship it is often between things many times removed from the problem at hand. For the data of this study it was finally decided to classify on the basis of the students' verbal commitment to the hypothesis. Thus

a student might make a diffuse implication such as, "Does the light cause it to happen?", without too much risk. On the other hand the question, "Does light make electrons move?", conveys much more information and the student is thereby involved in a situation of greater risk.

Table XIV and Table XV report the degree of participation in the diffuse and directed implication categories. There was no association reported between frequency of use and treatment for either. All treatment groups made extensive use of this type of question. Figure 5 indicates that between twenty-five and fifty percent of the questions asked by all groups belong to one of these sub-categories. The directed relationship is the preferred one of the two.

Treatments sponsor very little of the variance accounted for by the regression equations of these two categories ; nor do the other variables except fluency. The number of questions asked is the only major contributor to the categories corresponding to participation by means of these two kinds of questions.

Concrete-inferential Implication. This division of the implication questions is concerned with manipulation of concrete variables to provide data from which inferences could be made. There are three subtypes according to the kind of manipulation involved. They are best defined by examples selected from the collected data. Elimination, (e.g. "If the light had been removed would the needle of the electroscope move back to where it was at the beginning?"). Substitution, (e.g. "If you used a heat lamp instead would it still work?"). Addition, (e.g. "If the electroscope had been grounded would the light have affected it?").

TABLE XIV

DIFFUSE ABSTRACT-CONCEPTUAL IMPLICATION
NUMBER OF PERSONS X FREQUENCY
OBSERVED AND (EXPECTED)

	frequency 0	1 - 2	3 or more
GROUP A	23	14	3
	(20.8)	(12.8)	(6.4)
GROUP B	16	16	5
	(19.3)	(11.8)	(5.9)
GROUP C	43	18	11
	(37.5)	(23.0)	(11.5)
GROUP D	29	20	15
	(33.4)	(20.4)	(10.2)

$X^2 = 10.08$, $df = 6$, N.S.

TABLE XV

DIRECTED ABSTRACT-CONCEPTUAL IMPLICATION
NUMBER OF PERSONS X FREQUENCY
OBSERVED AND (EXPECTED)

	frequency 0	1 - 5	6 or more
GROUP A	21	14	5
	(14.1)	(16.7)	(9.2)
GROUP B	13	13	11
	(13.0)	(15.5)	(8.51)
GROUP C	21	36	15
	(25.4)	(30.1)	(16.6)
GROUP D	20	26	18
	(22.5)	(26.7)	(14.7)

$X^2 = 9.6$, $df = 6$, N.S.

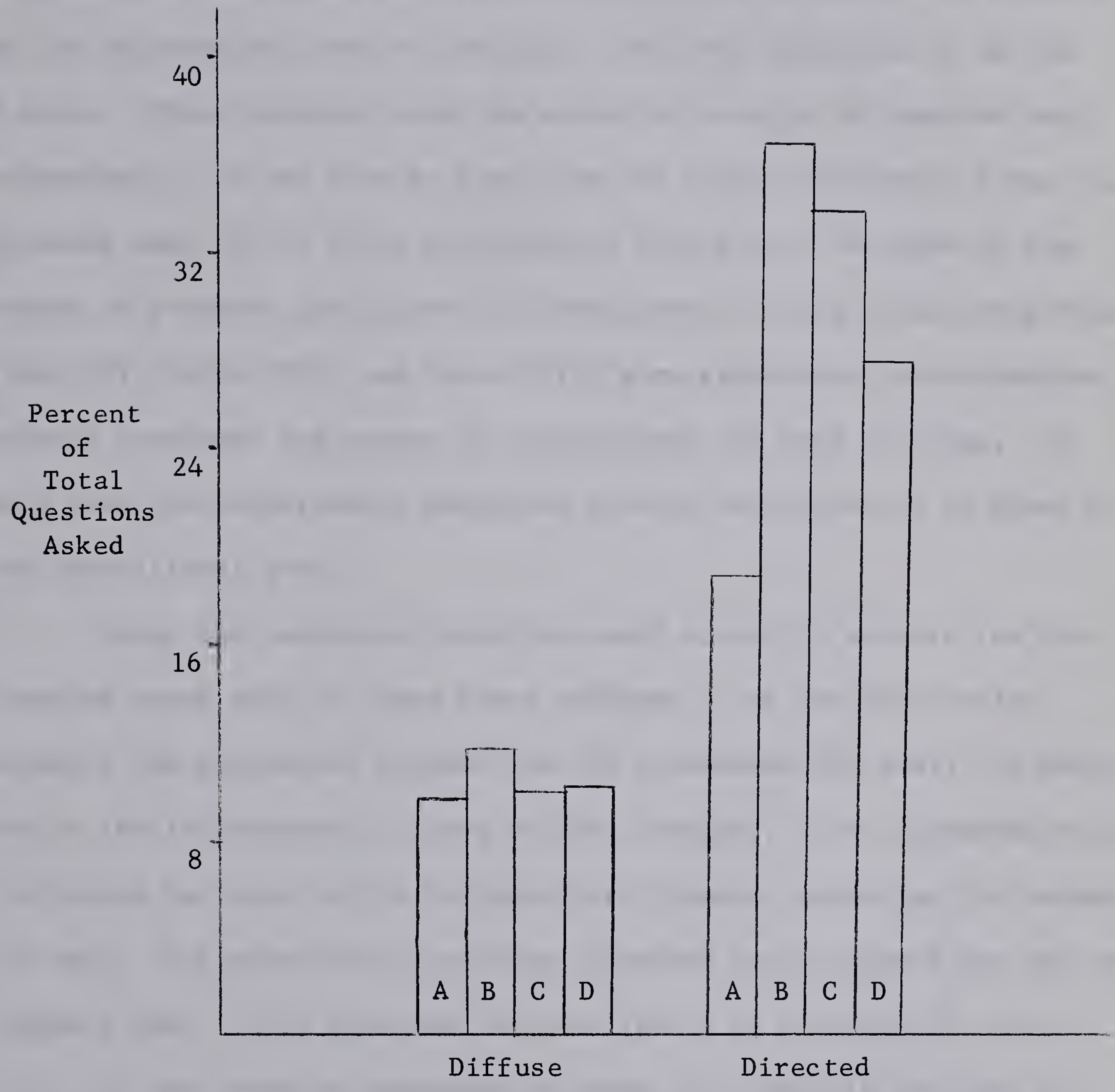

Figure 5

Percent of Questions in the Sub-categories of Abstract-Conceptual Implication for the Four Groups

Neither of these categories was used extensively to aid in inquiry. Figure 6 shows that the frequency with which these types of questions were asked was slight particularly in the groups treated by the hypothetical mode of teaching. The only exception is in the A group. These students used the substitution type of question very extensively. It can also be seen from the figure that Group A was the greatest user of all three questions of this type. In terms of the number of students participating through use of these three categories, Table XVI, Table XVII, and Table XVIII show significant relationships between treatment and number of participants for each of these. In each case the relationship indicates greater participation in Group A, the expositional group.

Again the regression equation would appear to support the conclusions about each of these three subtypes. For the elimination category the regression weights for the treatments are small, no doubt due to the low frequency of use of this category. But treatments account for twenty per cent of the variance with fluency accounting for seventy per cent. The substitution category provides ample support for the contingency test. With treatment weights from A to D being .20, -.01, -.02, .05 the combined treatments account for sixty-six per cent of the variance while fluency contributes only twenty-one per cent. The indication seems to favor the previous result that Group A was a frequent user of this type of question.

The category of addition provides the most definite indication of support for the chi square significance. Treatments predicted seventy-seven per cent of the accountable variance, the regression

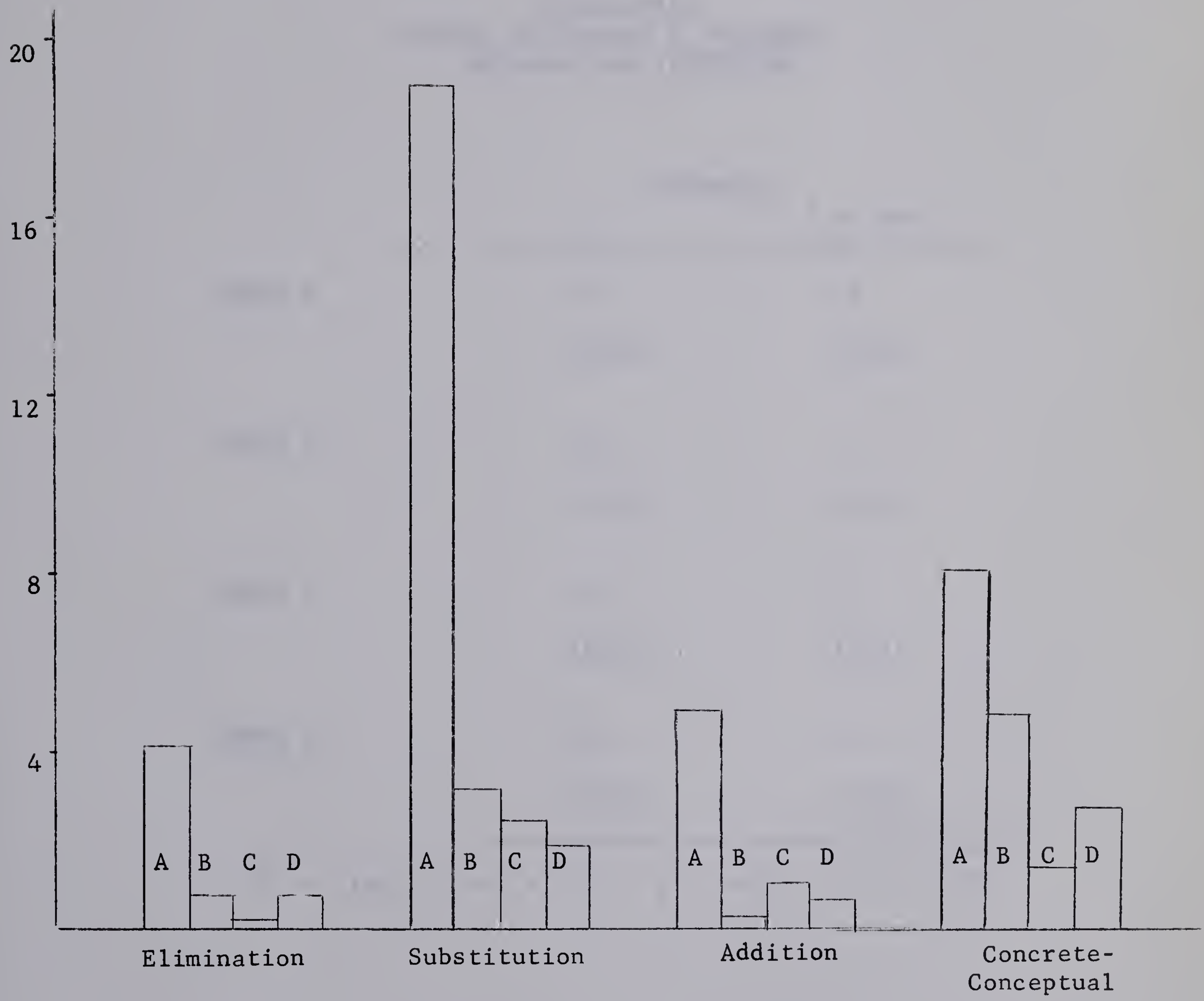

Figure 6

Percent of Questions in the Abstract-Conceptual and Concrete-Conceptual Categories for the Four Groups

TABLE XVI

ELIMINATION
NUMBER OF PERSONS X FREQUENCY
OBSERVED AND (EXPECTED)

	frequency 0	1 or more
GROUP A	29	11
	(35.5)	(4.5)
GROUP B	34	3
	(32.8)	(4.2)
GROUP C	70	2
	(63.9)	(8.1)
GROUP D	56	8
	(56.8)	(7.2)

$X^2 = 16.2$, $df = 3$, p .01, $C = .27$

TABLE XVII

SUBSTITUTION
NUMBER OF PERSONS X FREQUENCY
OBSERVED AND (EXPECTED)

	frequency 0	1 or more
GROUP A	9	31
	(27.0)	(13.0)
GROUP B	30	7
	(25.0)	(12.0)
GROUP C	58	14
	(48.7)	(23.3)
GROUP D	47	17
	(43.3)	(20.7)

$X^2 = 46.7$, df = 3, $p < .01$, C = .42

TABLE XVIII

ADDITION
NUMBER OF PERSONS X FREQUENCY
OBSERVED AND (EXPECTED)

	frequency 0	1 or more
GROUP A	26	14
	(35.1)	(4.9)
GROUP B	36	1
	(32.5)	(4.5)
GROUP C	67	5
	(63.2)	(8.8)
GROUP D	58	6
	(56.2)	(7.8)

$X^2 = 24.8$, $df = 3$, $p < .01$, $C = .32$

weights A to D being respectively .58, -.02, .00 and .04. Almost all of the remaining predicted variance was supplied by the fluency score.

Concrete-conceptual Implication. This last category holds those questions in which the student attempts to determine the necessity of an object in order that the phenomenon occur. (e.g. "Does the electroscope have to be charged with cat's fur in order for this discharge by light to take place?"). Table XIX records the fact that the expositionally treated group used this type of question much more widely than the three groups taught in the hypothetical mode. Reference back to Figure 6 indicates, too, that a higher proportion of the questions asked by students of Group A fell into this category.

The regression equation indicated that seventy-five per cent of the variance predicted for this vector was provided by the four treatment vectors. Once again the only other predictor which appears to contribute other than a negligible amount is the fluency score. The weights of the treatment vectors agree with the statement that Group A was the most frequent user of this question type. From A to D they were .32, -.09, .02, and .01.

Summary. In attempting to put hypothesis 2.2 to the test, analyses were made of each question category in terms of the number of students asking the type of question, and the proportion of the total questions assigned to each category. Results were compared among four treatment groups. Table XX presents a review of the findings. Caution must be exercised in terms of the interpretation of the tabulated summary, however. The regression weights are included for qualitative description only. They have no relation to the significance levels

TABLE XIX

CONCRETE-CONCEPTUAL IMPLICATION
NUMBER OF PERSONS X FREQUENCY
OBSERVED AND (EXPECTED)

	frequency 0	1 or more
GROUP A	26	14
	(30.2)	(9.8)
GROUP B	26	11
	(28.0)	(9.0)
GROUP C	63	9
	(54.4)	(17.6)
GROUP D	46	18
	(48.4)	(15.6)

$X^2 = 9.0$, $df = 3$, $p < .02$, $C = .20$

TABLE XX

REVIEW OF FINDINGS FROM THE QUESTION ANALYSIS

Category	Treatment Regression wts.** A	B	C	D	X^2	p
Categorical verification	-.17	-.13	.04	.00	11.49	n.s.
Condition-descriptive	.01	-.09	.00	.13	12.60	n.s.
Condition-comparative	-.20	.00	-.02	.01	10.98	n.s.
Structural-component	-.15	-.08	.00	.00	9.80	.02
Properties check	-.03	.00	.22	.17	11.63	<.01
Diffuse relationship	-.12	.00	.00	.11	10.08	n.s.
Directed relationship	-.07	.00	-.03	.00	9.60	n.s.
Elimination	-.11	-.04	.09	.00	16.20	<.01
Substitution	.20	-.01	-.03	.05	46.70	<.01
Addition	.58	-.02	.00	.04	24.80	<.01
Concrete-conceptual	.32	-.09	.02	.01	9.00	.02

** in the presence of STEP Science, Pre-Achievement, Q Sort and Fluency Scores. These weights have descriptive value only.

reported for the chi square statistic for each category. However, the ranking of each regression weight is identical to the ranking of the cells of the contingency tables. The inclusion of the regression weights here is to point out that in the presence of other factors there would appear to be little reason for viewing the results of the non-parametric tests as suspect. Of considerable import would seem to be the fact that ability and achievement scores, as well as the Q Sort scores, appear to be of little value in the prediction of the types of questions which a student asks. On the basis of the results tabulated it would appear that the null hypothesis 2.2 must be rejected. The pattern of questions asked by students relevant to a problem is dependent upon the information input.

Analysis of Test Data

So that the analysis of verbal interaction might be viewed in perspective a control variable measuring achievement in the conventional sense of information recall was subjected to regression analysis. Table XXI shows the intercorrelations among the variables used in the study. For this analysis all twelve classrooms were used. From the total sample of 354 students only 323 could be used for various technical reasons. Many of the low correlations are not surprising in view of the fact that the Q-Sort Scales were attempting to measure student perception of independence rather than a purely cognitive variable.

Relationships among pre and post test scores. Table XXII shows the means, standard deviations, and t-tests for the pre and post experiment test scores on the Achievement Test, You-Sort, and Teacher-

TABLE XXI

INTERCORRELATIONS AMONG VARIABLES

N 323

STEP Science	1.00	0.00*	0.06*	0.38	0.51	0.17	0.06*
You-Sort (pre)		1.00	0.33	0.08*	0.09*	0.50	0.35
Teacher-Sort (pre)			1.00	0.02*	0.06*	0.42	0.48
Achievement (pre)				1.00	0.51	0.13	0.03*
Achievement (post)					1.00	0.18	0.01*
You-Sort (post)						1.00	0.42
Teacher-Sort (post)							1.00

* Not significant.

TABLE XXII

MEANS, STANDARD DEVIATIONS AND T TESTS FOR REFERENT VARIABLES

Group	N	STEP Science $\overline{X}$		Achievement Pre $\overline{X}$		Post $\overline{X}$		t	p
A	84	272.1	31.8	32.0	9.3	37.0	12.7	2.4	.01
B	73	281.1	9.9	36.0	11.8	44.7	14.5	4.2	.001
C	86	277.6	8.9	34.2	10.6	40.1	10.8	4.2	.001
D	80	272.9	9.6	32.3	9.8	35.6	11.5	2.8	.005
		F = 4.15		F = 2.4					
		p = .007		p = .06					

Group	N	You-Sort Pre $\overline{X}$		Post $\overline{X}$		t	p	Teacher-Sort Pre $\overline{X}$		Post $\overline{X}$		t	p
A	84	74.6	6.6	72.2	7.2	1.1	ns	69.9	10.0	71.8	9.3	0.7	ns
B	73	72.9	4.8	74.4	7.2	2.9	.01	72.2	6.4	71.4	6.4	2.0	ns
C	86	74.0	6.0	73.7	6.0	0.7	ns	74.7	7.0	74.9	7.9	0.4	ns
D	80	73.4	5.8	72.9	5.7	1.3	ns	72.1	6.0	72.2	6.8	0.1	ns
		F = 0.8						F = 4.5					
		p = .51						p = .004					

Sort, and it also shows means and standard deviations for the STEP Science scores. An analysis of variance was carried out on the STEP Science scores and all the pre-test scores across groups. The resultant F ratios and probability levels are included at the base of the table.

All four groups showed significant gain on the Achievement Test. Changes in the You Sort and Teacher Sort scores were negligible. In addition, it should be noted that at the beginning of the experiment there was a significant difference ($p = .007$) among groups on the STEP Science test. This meant that Group D, an inquiry group began with a slight disadvantage.

Hypothesis 3.0 This hypothesis postulated no significant differences across treatment groups with respect to achievement. A number of other variables were included in the regression analysis and each one tested for significance of contribution using an F test. The results are recorded in Table XXIII. The results of these tests for a particular variable have meaning only in the presence of the variables included in the regression equation.

It is very significant to note that no group performed better than any other once initial differences had been accounted for. This is the more significant in view of the fact that the test emphasized the kind of informational knowledge included in the presentation to the expositional classes. Students in the classes taught by the hypothetical mode as defined for this experiment often did not gain knowledge of the appropriate labels for the phenomena into which they inquired. It must be admitted however, that in no instance was a

class unable to successfully explain a problem during the experimental periods of inquiry. Often the explanation remained at an intuitive level. When this disadvantage is added to initial differences in ability unfavorable to the inquiry group, full appreciation of the significance of achievement of this group is felt.

The fact that the STEP Science Test, a test of science ability and aptitude, and the pre test of Achievement, both contribute very significantly to the post test of Achievement was to be expected. In both cases the probability of the contribution occurring due to chance alone was less than 0.00001.

Hypothesis 4.1 It was felt that being placed in a treatment group where an unusual degree of student autonomy was required for successful performance, a student's perception of the roles he and his teacher ought to play in the teaching-learning experience would be an important factor in achievement. This part of hypothesis four dealt with the student role perception and postulated that as measured by the You-Sort instrument there is no significant contribution to achievement on the basis of the students' perceived independence. This is shown in Table XXIII by the restriction of variable X_8 from the regression equation. The null hypothesis is supported on the basis of this analysis.

Hypothesis 4.2 In a fashion analogous to that above it was postulated that the aspect of perceived independence measured by the Teacher-Sort would make no significant contribution to the achievement of the student. Again as shown in Table XXIII by the restriction of Variable X_9, the null hypothesis is accepted.

TABLE XXIII

CONTRIBUTIONS OF VARIABLES WITH
ACHIEVEMENT AS CRITERION.

N = 323

	Restriction	RSQ	Difference	df	F Ratio	Probability
X_1	Sex	.3906	.0075	1/314	3.89	0.05
X_2	Step Science	.3152	.0829	1/314	43.21	0.00001
X_3	Pre Achievement	.2907	.1074	1/314	56.01	0.00001
X_4-X_7	Treatments	.3826	.0155	4/314	2.02	N.S.
X_8	Pre You Sort	.3934	.0047	1/314	2.41	N.S.
X_9	Pre Teacher Sort	.3980	.0001	1/314	--	N.S.

REGRESSION EQUATION

$$Y = -2.08X_1 + 0.40X_2 + 0.16X_3 + 0.02X_4 + 0.44X_5 + 0.0X_6$$

$$+ 4.03X_7 + 0.99X_8 - 0.43X_9 - 100.04$$

RSQ = .3981

Hypothesis 4.3 The possibility that the new roles played by students during the experimental period would contribute to a change in the perception of independence was explored by this hypothesis. It postulated that there would be no differences in the post-test scores of the You-Sort among the groups. Table XXIV indicates there was no difference among treatment groups in the presence of several variables when the post experiment scores of the You-Sort were the criterion for a regression analysis. Major contributors to the variance of the measure were the pre test of the You-Sort ($p < 0.00001$), the pre test of the Teacher-Sort ($p < 0.0001$), and the STEP Science Test ($p < 0.01$). The first two of these are expected results since these two and the criterion measure are intimately related. The contribution of the STEP Science Test is more interesting. It can perhaps be explained by postulating that the better student as measured by the science test has also learned well the idealized role of the student even though this may have no relation to his actual behavior, or to the behavior desired of him by the classroom authority.

Hypothesis 4.4 This hypothesis postulated that there would be no significant difference in scores on the post test of the Teacher-Sort. Table XXV presents the analysis of the regression equation on this measure. Again the expected contribution from the pre tests of the You-Sort and Teacher-Sort give no cause for concern. They make very significant factors.

Hypothesis 5.0 This hypothesis was formulated to explore contributions to achievement on the three major criteria already discussed from such factors as science knowledge and aptitude, sex, and

TABLE XXIV

CONTRIBUTIONS OF VARIABLES WITH
POST-YOU SORT AS CRITERION

N = 323

	Restriction	RSQ	Difference	df	F Ratio	Probability
X_1	Sex	.3507	.0013	1/314	0.63	N.S.
X_2	STEP Science	.3381	.0139	1/314	6.73	0.01
X_3	Pre-Achievement	.3511	.0009	1/314	0.43	N.S.
X_4-X_7	Treatment	.3443	.0077	4/314	0.93	N.S.
X_8	Pre-You Sort	.2087	.1433	1/314	69.41	0.00001
X_9	Pre-Teacher Sort	.2910	.0610	1/314	29.54	0.0001

REGRESSION EQUATION

$$Y = 0.55X_1 + 0.09X_2 + 0.46X_2 + 0.24X_4 + 0.02X_5 + 0.09X_6 + 1.47X_7 + 0.0X_8 + 0.53X_9 - 3.39$$

RSQ = .3520

TABLE XXV

CONTRIBUTIONS OF VARIABLES WITH POST-TEACHER SORT AS CRITERION.

N = 323

	Restriction	RSQ	Difference	df	F Ratio	Probability
X_1	Sex	.2812	.0232	1/314	10.49	0.001
X_2	STEP Science	.3009	.0035	1/314	1.60	N.S.
X_3	Pre-Achievement	.3044	--	1/314	--	N.S.
X_{9-12}	Treatment	.2881	.0163	4/314	1.85	N.S.
X_4	Pre-You Sort	.2692	.0352	1/314	15.90	0.0001
X_5	Pre-Teacher Sort	.1782	.1262	1/314	57.00	0.00001

REGRESSION EQUATION

$$Y = 2.41X_1 + 0.05X_2 + 0.27X_3 + 0.40X_4 + 0.0X_5 + 1.19X_9 - 0.83X_{10} + 1.88X_{11} + 0.47X_{12} + 8.22$$

RSQ = .3044

the degree to which the student participated in the verbal interaction of the experiment.

The contribution of the first two of these has been presented in Tables XXIII, XXIV and XXV. The effect of the science score has been discussed in the foregoing paragraphs. Sex was found to be a significant factor in the analysis of the Achievement Test and in the analysis of the post Teacher-Sort. Neither of these results conflicts with existing knowledge. Table XXVI shows the means of all variables used in the analysis by group and by sex within group. It can be seen that boys outperform girls on both tests of science achievement. On the other hand girls outperform boys in all but two cases in the group analysis of scores on both pre and post test You-Sort and Teacher-Sort scores. Girls appear to perceive a role of greater independence than boys.

With regard to the contribution of participation it is noted that the normal distribution of scores is not required for a predictor during a regression analysis. If the assumption is made that the number of questions a student asks provides a scale of independent scores (as Suchman assumed), then the effects of student participation upon the three major criteria can be investigated. However, interpretation of the F statistic would be rather difficult. This type of analysis was performed and the results are presented in Table XXVII. The contributions of this fluency score appear negligible. These results were obtained in the presence of the other variables of the analysis.

Some other considerations. In addition to exploration of the main hypotheses the regression technique was used to identify possible

TABLE XXVI

VARIABLE MEANS BY GROUP AND BY SEX WITHIN GROUP

Group	Sex	N	VARIABLES[a] X_2	X_3	X_4	X_5	X_6	X_7	X_8
	Boys	48	277.9	74.9	70.4	33.1	39.1	73.2	71.2
GROUP A	Girls	36	272.3	75.9	71.4	31.6	35.8	72.8	74.5
	Total	84	275.5	75.3	70.8	32.4	37.7	73.0	72.6
	Boys	29	282.6	72.8	73.0	37.2	48.4	75.0	70.3
GROUP B	Girls	44	280.1	73.0	71.6	35.1	42.2	74.1	72.1
	Total	73	281.1	72.9	72.2	36.0	44.7	74.4	71.4
	Boys	43	279.1	73.3	73.0	35.2	41.4	72.1	72.0
GROUP C	Girls	43	276.2	74.8	76.4	33.2	38.8	75.3	77.8
	Total	86	277.6	74.0	74.71	34.2	40.1	73.7	74.9
	Boys	33	271.8	73.2	71.8	33.2	37.7	72.1	72.0
GROUP D	Girls	47	273.7	73.6	72.3	31.7	34.0	73.4	72.4
	Total	80	272.9	73.4	72.1	32.3	35.6	72.9	72.2

[a]X_2 = Step Science Test

X_3 = Pre You Sort

X_4 = Pre Teacher Sort

X_5 = Pre Achievement Test

X_6 = Post Achievement Test

X_7 = Post You Sort

X_8 = Post Teacher Sort

TABLE XXVII

EFFECT OF PARTICIPATION
ON THREE CRITERIA

N 272

Predictor	Criterion	RSQ full	RSQ restricted	Difference	df	
No of questions	Achievement	.425	.420	.005	1/262	N.S.
	You - Sort	.366	.366	---		N.S.
	Teacher-Sort	.276	.273	.003	1/262	N.S.

interactions among variables. Regression analyses studying the interaction Step Science X Treatment and the interaction Sex X Treatment showed no significant contributions in the presence of the other variables, on the three criteria studied.

A score which was formed from the difference of the pre test You-Sort and Teacher-Sort was considered to measure the degree of typicality of the student. This score in the typical case would be positive, the student perceiving the teacher as a threat to his independence. This variable made no contribution to the three main criteria in the presence of the others.

An attempt was made to compare patterns of questioning sampled from different developmental stages of the experiment. This was accomplished by dividing the transcripts from each class into twenty question portions from the start of film one through to the end of film six. Although no differences were detected within a class across time an interesting observation was made. For the inquiry groups given minimum input stimuli a significantly higher rate of occurrence of questions in the abstract-conceptual categories was noted in the twenty question portions at the beginning of the inquiry period following every filmed presentation. Table XXVIII compares the observed frequency of combined Directed and Diffuse subtypes with expected frequencies based upon their occurrence over the total sample of questions.

TABLE XXVIII

ABSTRACT-CONCEPTUALIZED RELATIONSHIPS
OFFERED DURING THE FIRST TWENTY QUESTIONS
BY GROUP, OBSERVED AND (EXPECTED)

	O	E	O - E
Group A	74	(72)	2
Group B	116	(115)	1
Group C	193	(154)	39
Group D	188	(134)	54

$X^2 = 31.6$, df = 3, $p \ll .001$, C = .23

CHAPTER V

SUMMARY, CONCLUSIONS AND DISCUSSION, AND IMPLICATIONS

I. SUMMARY

The teaching of science in the traditional manner suffers disadvantages in the light of currently held views on the goals of science teaching. Many scientists and educators support an inquiry approach as a solution to the problem of reaching these goals. Teaching in what Bruner calls the hypothetical mode is claimed to provide the student ultimately with more powerful tools for learning than the more conventional mode of exposition. Past attempts at more intuitive approaches to teaching-learning have not been successful in that "recipes" for problem solving have often been treated in an expositional fashion. Inquiry has rarely been a major classroom strategy.

Before advocates of this rebirth of interest in intuitive approaches to teaching provide concrete descriptions of such methods, many facets of inquiry should be studied. Without such investigations, any set of directions for heuristic methods of teaching is likely to be naive and/or misunderstood. This study constituted a probe into what was believed to be a fundamental factor of inquiry teaching. It was assumed that one characteristic which distinguishes points on a continuum from hypothetical to expositional modes of teaching is the amount of information relevant to the problem which is volunteered

by the teacher, without the necessity of student action. Through controlled variation in information input this study attempted to investigate the effect on quantity and quality of verbal inquiry, and to relate the result to measures of ability, achievement and perception of independence.

The major theoretical model used to delimit the study was a model of inquiry based on information processing. This model defines a system of question categories according to the function of the question posed in ongoing inquiry. Assignment of a particular question to a category is dependent on the judgment of the investigator. To facilitate this decision process students were asked to structure their questions so that "yes" or "no" answers were appropriate. The control of information input was accomplished through production of sound motion pictures of the problems used in the study. Three variations of each film were used. For what was called the hypothetical mode, a visual presentation of a phenomenon which could serve as the basis for a problem was presented. An intermediate mode required visual and verbal presentation of the phenomenon and identification of the problem. A sound film of the complete problem and its explanation provided the input for the expositional mode which served as the basis of comparison for the inquiry groups.

Twelve randomly selected grade eight classes were used for the study. They were assigned to four treatment groups of three classes each, corresponding to the three variations of input, plus a group instructed by the hypothetical mode but given the benefit of

instruction regarding the function of inquiry. This group was established to determine the effect, if any, of short term instruction upon the mental set of students toward a more conventional role. Each class was shown the appropriate version of six problem films over an experimental period ranging from two to three weeks.

Control variables, used to aid in the intrepretation of the inquiry analysis, included: a science aptitude and ability test, the S.T.E.P. Science Test, Form 3A; a test of student perception of his role in the teaching-learning process, the Q Sort Instrument; and a test of achievement related to the content of the problems used in the study, the Achievement Test. The Q Sort Test and the Achievement Test were administered both before and after the experimental period. The measurement of inquiry was accomplished through analysis of tape recordings made of the question periods following each filmed presentation.

II. CONCLUSIONS AND DISCUSSION

It is convenient to group the contents of this section under three headings. The discussion deals with verbal inquiry, test performance, and some related considerations.

A. Verbal Inquiry

Quantity of Inquiry. Hypothesis 1.0 postulated no difference in the quantity of inquiry due to varied information input. The quantity of inquiry stimulated by the filmed presentations refers to the proportion of student participants and their fluency in questioning.

Variation in information appeared to affect only the latter dimension of the quantity of inquiry. The proportion of students participating was not affected by varying the information input.[1] This finding suggests that other factors, perhaps closely related to the personality or affective dimensions of student behavior, are more important determinants of inquiry for particular individuals. It was expected that the minimized input which defined the hypothetical mode of teaching for this study would induce higher arousal and perhaps increase participation. This expectation seems to be supported by the increased fluency scores for those individuals who _did_ participate in inquiry in the lower input groups. It would seem then, that the increase in arousal was effective but that it was of little consequence as far as inducing individuals to _begin_ inquiring was concerned. It may be that the reduction in information simultaneously raises the degree of risk inherent in participation thus inhibiting overt behavior. Such a conclusion is warranted by the findings of Bruner with regard to the effect of the element of risk upon individual inquiry patterns.[2]

Although the increase in fluency from Group A to Group C can be explained by the necessity for students in those groups to discover an increasing number of elements relevant to the problem, an increase from Group C to Group D is less readily explained according to prior assumptions. The problem is further complicated by closer scrutiny of

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[1]See Table VI.

[2]Jerome S. Bruner, Jacqueline J. Goodnow and George A. Austin, _A Study Of Thinking_ (New York: John Wiley & Sons, Inc., 1956), pp.113-124.

the available data. It was shown that although students of classrooms 10, 11, and 12, (Group D - hypothetical mode with prior instruction), asked a greater number of questions than those of classrooms 07, 08, and 09, (Group C - hypothetical mode with no instruction), there were proportionately fewer participants in the former group.[3] In addition, the data from the pre experiment testing period indicates that Group D had lower mean scores on all covariables than did Group C.[4] The only difference in treatment introduced in this study was the single period of instruction regarding the function of questioning for discovery which was provided the classes of Group D. The success of many studies in manipulating set through verbal instruction,[5] encourages the explanation that a more appropriate set towards participation was induced by this limited instruction.

Quality of Inquiry. In Hypothesis 2.0 it was speculated that a variation of information input would not affect the quality of inquiry. The quality of inquiry refers to the patterns of question types elicited by the different film presentations. The variation in input did affect the quality of student inquiry. It is to be expected that patterns of inquiry, or strategies, are situation specific. What was more interesting were the relationships between patterns and the amount of supplied

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[3]Refer to Table V and Table VIII.

[4]See Table XXII.

[5]A brief comment on a few such studies is found in Chapter II, on page 41 of this report.

information. Each of the five major categories of question types used in the analysis is considered below.

1. Categorical Verification. There was little apparent difference in the use of questions of categorical verification among the four treatment groups.[6] This was unexpected since both Group A and Group B were given full verbal descriptions of the problem and apparatus. Yet, questions in this category are used to specify the classes to which objects belong. It was expected that Groups C and D would demonstrate greater use of such questions. It may well be that some inquirers of all groups made use of this category to satisfy a desire to participate on a level which incorporated far less risk than a more hypothetical question would. This conclusion appears warranted since inspection of the transcripts of inquiry sessions reveals that not only did Groups A and B use this category to reiterate supplied information, but a comparable proportion of participants in all groups used this reiteration process, often two or more times.

2. Analytical Verification. The treatment groups used two of the four question types of this category with a degree of difference that was statistically significant. Properties check questions and those of the structural-component kind were asked by more students from groups B, C and D which were instructed in the hypothetical mode.[7] With decreasing information input it became more necessary for students to check elements of the problem situation. However, it was unexpected

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[6] cf. Table VIII and Figure 3.

[7] Refer to Tables XII, and XIII.

that Group A and Group B would exercise the other two of the four question types of this category to an extent equal to Groups C and D. The condition-descriptive and condition-comparative questions would logically be used to analyze the components of the problem situation leading to a statement of the problem. In Groups A and B these tasks were accomplished through the nature of the initially supplied information. Yet the students of these groups participated as frequently as students from Groups C and D, through questions of both types.[8] One possible explanation might be that this type of question is some indication of speculation about a higher level relationship. This implication will be discussed below.

3. Abstract-conceptual Implication. All four treatment groups were frequent users of question types of this category. There were no statistically significant differences across groups with respect to the number of inquirers asking questions of either a directed or diffuse nature.[9] It was in Group B that this category was most frequently used. Of the three groups of students being treated in the hypothetical mode, Groups B, C and D, students of the B group were presented with the most structured input. Having been presented with a problem situation which was analyzed for them, and for which the problem was explicitly formulated, they were ready almost at once to formulate reasonable relationships using questions of this category. Students of the other two inquiry groups, because of the minimized input, required a large

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[8]Refer to Tables X, and XI.

[9]Refer to Tables XIV and XV.

proportion of the inquiry period merely to verify and analyze components of the situation. Proportionately less time was therefore available to them for questions of this category. For all three inquiry groups, B, C, and D, the directed abstract-conceptual relationship was the most frequently used specific question type.[10]

4. Concrete-inferential Implication. The questions subsumed by this category provided the most interesting finding. None of the three question types, (elimination, substitution, and addition), was used extensively by any group, except the substitution type in Group A.[11] It may be safe to state that these questions were vastly underestimated by the students in their power to aid in inquiry. Students appear to find this type of verbal function considerably more difficult than any other. More than this, and more important, these questions are usually restricted to roles other than experimentation prior to discovery. Based on evidence from Group A (the only group using this category to any extent) it appears that two methods are used by students to complete assimilation of a problem solution. One is to reword and restate the correct relationship once it has been identified. An equally common method is to experiment with the problem parameters in a manner predicted to give affirming responses based upon the knowledge of an appropriate relationship. For example, having discovered that the removal of air from a bell jar creating reduced pressure was the major cause of the phenomenon observed in one problem film,

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[10]See Table VIII.

[11]cf. Figure 6 and Table XX.

a student was prompted to ask this question of substitution. "If the bell jar were not completely air tight, would it still work?"

This is not to say that this category of questions is never used for more sophisticated purposes in terms of the inquiry. But it was evident throughout the experiment that frequent use of this category seemed to relate more to satisfying this role of approval seeking than the role of active inquiry.

5. Concrete-conceptual Implication. Into this category fall those questions in which the student attempts to identify the necessity of an object in order that the observed phenomenon will occur. Much the same could be said regarding this category of questions as was said for the previous one. Again this is a type of question which could have great import in inquiry. Students, on the other hand, knowing how conceptually to use it, reserve this function for purposes more in line with the nature of the expositional classroom. Such uses of these question categories are, perhaps, means of identifying the pervasiveness of what Schwab calls the "rhetoric of conclusions" with which science has been identified.[12] Students are more oriented towards correct answers than towards the ability to inquire about the nature of scientific answers.

In addition to the information regarding the quality of inquiry conveyed by a comparison across groups of gross numbers of questions of a given type, information of a different nature came from another

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[12]Joseph J. Schwab, "The Teaching of Science as Enquiry," The Teaching of Science, Joseph J. Schwab and Paul F. Brandwein (The Inglis and Burton Lectures, Harvard University, 1961. Cambridge, Mass.: Harvard University Press, 1962), p.24.

kind of analysis. In attempting to discover whether there were changes in the patterns of inquiry occurring over the period of the experiment, the samples of inquiry from all twelve classes were divided into five minute portions and examined by comparing class periods one to six for each room. No change in inquiry techniques was evident. However, an interesting pattern was discovered. In all classes, and for all periods, the proportion of abstract-conceptual implication questions was higher in the first five minutes than for any other five minute segment and higher than for the total inquiry session. This was especially true of the inquiry groups.

This observation is perhaps related to the paucity of information input and represents the trial and error attempts to reduce the grossness of the task of assimilation immediately. The focus was on finding the correct answer, not on the nature of the search. Questions which postulate relationships in such a manner that they must be completely accepted or rejected are inefficient, particularly at early stages of an inquiry session. But only after fruitless attempts to resolve the situation by an intuitive guess do the students settle into a more stable and productive pattern of inquiry with its inherent reduction in risk.

Once stable patterns of inquiry were developed, it became evident that the particular pattern which evolved depended upon the information initially presented. Considering the two teaching styles underlying this study, by a mode of exposition or by a more hypothetical mode, the inquiry patterns elicited by the two appear to have distinct features. In both cases the immediate reaction is to assimilate the data by profuse and diffuse postulations of hypothetical relationships.

These are advanced in such a manner that they must either be accepted or rejected with little net gain in information. These initial attempts are often frustrating to the inquirer who, having failed in a total manner, reacts as though there are no other paths available to him. Following these initial probes a more stable and efficient pattern of inquiry gradually emerges. Expositionally taught students tend to experiment by verbal manipulation of variables apparently to clarify a relationship with which they have been provided and which they have accepted. Some verification is also attempted. Students who were exposed to a more hypothetical mode of teaching follow the initial trials with more deliberate analytical verification questions. After much data has been accumulated and juxtaposed in several ways, students' attempts at hypothesized relationships are usually more successful. Otherwise the chain of events is repeated. Following discovery of the problem solution, the pattern becomes similar to that elicited by the expositional presentation.

The hypothesis postulating no differences in patterns of inquiry due to variations in information input (Hypothesis 2.0) can be rejected on the basis of the foregoing discussion. It seems reasonable to conclude that patterns of inquiry are specific to the information processing problem presented to the student. Students seem capable of using all of the verbal functions identified by the Suchman model, but often make inefficient use of them. Some of the functions are used more often by the inquirer than their value would merit, while others are used seldom or apparently for less powerful purposes than they might serve.

Before concluding the discussion regarding verbal inquiry, one can counter the claim of those who would reserve inquiry for the more able student. The use of the regression approach to category analysis strongly indicated that the only predictors of verbal participation in hypothetical teaching situations as defined for this study are fluency and treatment. Measures of ability and aptitude, of previous achievement, and the Q Sort measures of role perception were all poor predictors of participation in any question category. This was the case whether the type of question concerned the mere naming of apparatus or the more difficult inferential hypothesis. If, as assumed in this study, one value of inquiry teaching is the exercise of various means of data processing, then this aim appears to be served regardless of ability, previous knowledge as measured by conventional achievement tests, or present role perception.

B. Test Performance.

Achievement. The third hypothesis of the study postulated that there would be no difference in achievement during the experiment for the four groups. The results lead to an acceptance of the null hypothesis. Students from all groups did equally well on the final achievement test in the presence of controls from scores of the pre-experiment testing period.[13] The Achievement Test stressed achievement in the conventional sense in that it emphasized information recall and application. Students exposed to the hypothetical mode of teaching often did not discover "labels" appropriate to the phenomena

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[13]As indicated in Table XXIII, knowledge of treatment made no contribution to the variance of achievement.

of the problems. Their discovery of the underlying principles may be often intuitively understood though inadequately verbalized. Thus, the test was intentionally biased in favor of the expositional group. The results of this study do not substantiate charges made against the effectiveness of learning through hypothetical modes of teaching.

It is significant that the degree of participation, or no participation at all, has little or no effect upon achievement.[14] This finding, in addition to the fact that ability and pre-experiment measures of achievement fail to predict participation, suggests a needed reorganization of science achievement measures if the assumptions underlying inquiry teaching are valid. Conventional measures of achievement, by themselves, may be inadequate to assess the goals of science teaching reflected in recent programs for high school science.

Q Sort. Hypothesis 4.0 concerned the degree to which knowledge of a student's perception of independence would predict his behavior in an inquiry oriented classroom and the degree to which that perception would change during exposure to a hypothetical mode of instruction. In both cases the perception of independence was measured by the Q Sort Instrument.

Used as a predictor, this instrument made no contribution to the assessment of quantity or quality of participation.[15] It apparently

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[14]This finding, recorded in Table XXVII, was based on a limited number of the total experimental sample.

[15]This conclusion is based on the fact that the Q Sort scores contributed very little to the predicted variance of participation in all question categories.

measures a dimension not significantly related to the student's performance in an inquiry setting. It was expected that student participation would be affected by perception of role, particularly with regard to independence in the teaching-learning process. It may well be that what the student perceives "ought" to be, as measured by the Q Sort, has little or no relationship to his actual performance.

Using the Q Sort as a criterion gave equally insignificant results.[16] There was apparently no change in the factor being measured as a result of exposure to the inquiry role.

C. Related Consideration.

The lack of relation between student test performance and verbal participation in inquiry was cause for some concern. A closer search of the recorded data for possible explanations, led to one interesting finding.

It is not surprising to find in a group a person in the role of leader. Such was the case in group inquiry sessions and with interesting consequences. Identification of such a student could be made on the basis of his influence over the questioning patterns of his colleagues. Following a probe by him several questions would be posed in quick succession by other students. These would tend to cluster around the content of the initial question, to follow it in format, and would often be reworded reiterations of the same idea. The consequences of this behavior reflected the value of the lead probe. If it was suggestive, the questioning which followed tended to be productive. Otherwise, when the original had been rejected, succeeding questions would continue to pursue the same unproductive line of thought.

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[16] See Tables XXIV and XXV.

The importance of this phenomenon can be readily assessed. In order to promote and encourage individual inquiry of a productive nature the teacher must be aware of such group leaders, and of the small group of followers who may be present. Directing inquiry away from an unproductive line of thought is a valuable teaching function. The reverse phenomenon might equally be true. A valuable probe by a more isolated person would perhaps not be followed up, resulting in some loss of power in the questioning of the group.

Another observation on the experiment concerned the ability of teachers to cope with an inquiry situation. There appeared to be two relevant factors. The dominant style of the teacher was often reflected in his ability to give direct answers without elaboration, and his ability to stimulate student inquiry. The second factor concerned the teacher's academic ability. Sometimes questions were sophisticated for the grade eight level. In a few cases the teachers yes-no answers were incorrect, in many others, misleading. The usual difficulty appeared to be the teacher's lack of understanding of the scientific implications of questions.

Partial support for both of these points is available from the recorded data. The teacher of one class spent much of the first inquiry period volunteering information and elaborating student questions even though the experimental procedures had been clearly discussed. After the period of questioning following the first film presentation and a further consultation with the investigator, the amount of additional information supplied the students was decreased. But the teacher continued to talk an undue proportion of the time, often merely to restate

student questions or his own answers. With regard to the second factor, the teacher's ability to handle certain ideas, consider the following question offered by a student: "If a light which you couldn't see, a black light, was used would it still discharge the electroscope?" The teacher's reply was, "That wouldn't be a light, so the answer is no." Such rejection of a perfectly sound and pregnant query could hardly serve to advance inquiry in the classroom.

III. IMPLICATIONS

For Practice in the Classroom

Hypothetical Modes of Instruction and Achievement. Perhaps the most significant factor contributing to the rarity of inquiry oriented science teaching is a fear that students will in some way be jeopardized by not covering material in an expositional manner. In this study the traditional kind of achievement test was deliberately chosen to attempt to identify if there are grounds for such concern. As has been indicated, students instructed in the hypothetical mode did not perform significantly less well than students receiving more expositional instruction. It appears that inquiry oriented teaching can be advocated even though achievement examinations stress traditional goals. Since inquiry is claimed to contribute additional benefits to the learner and, as indicated by this study, does not jeopardize a student's performance, classroom teachers should not fear to consider such practice.

Evaluation of Inquiry. One of the more prominent implications arising out of this study concerns measures of achievement in science. Modern science programs organized around currently accepted goals can

not be appropriately assessed by traditional achievement tests. The results of this study suggest that both the quantity and quality of inquiry elicited from an individual are not correlated with such measures of achievement. Encouragement of individual inquiry and appropriate recognition of development in this ability is totally in the hands of the classroom teacher. Approval of student attempts at inquiry must not await appropriate instruments, although these must be developed.

The Inquiry Teacher. This study indicates that if the average science teacher in the junior high school attempts to teach through hypothetical modes he should be aware of two potential sources of difficulty. These are related to his command of the subject matter subject to the inquiry, and to his dominant teaching style (or, perhaps, personality type). It may be possible for the teacher to make an evaluation of his performance with respect to these two concerns. In conducting an inquiry class of the type described in this report as the hypothetical mode he would soon come to judge his adequacy in terms of the kinds of questions students pose. Perhaps what is required is a certain degree of confidence in the answers to students' questions. If a large number of the queries must be handled by the teacher with some lack of confidence, clearly, greater subject matter development is indicated. The second difficulty concerned the teacher's dominant teaching style and this can be assessed subjectively by replaying, for close scrutiny, tape recordings made during the conduct of

a normal lesson. Indications of over-domination, if it is present, are often quite apparent. More objective methods of assessment of such recordings are possible.[17]

The Dynamics of Groups. The inquiry teacher should also be aware of the group patterns within his classroom. It has been shown that, particularly in an inquiry situation, group leadership exerts considerable influence upon the potency of the sequence of subsequent questioning. Teachers should be aware of such patterns of behavior and be prepared to take advantage of them in promoting productive inquiry. It may well be that the more important of the roles of the inquiry teacher is that of director of group processes.

The approach to inquiry teaching within groups of average classroom size allows some students to remain inconspicuous if participation is left on a voluntary basis. If the assumption that there is value in participation is valid, then the teacher's responsibility is clear. Students who shun participation should be encouraged, perhaps by emphasizing and rewarding searching behavior itself at least as much as by emphasizing and rewarding the emitting of the correct response.

Inquiry Training for Students. The results of this study suggest that students do indeed need help in identifying and using effective strategies for inquiry. The Suchman model suggests that diffuse attempts to assimilate the total problem situation without previous

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[17]The method devised by Flanders is described in a book by Amidon and Flanders, and in a dissertation by Giammatteo, both of which are listed in the bibliography of this report.

analysis relies too heavily on subjective interpretations and intuitive understandings. Perhaps the student can be taught in the classroom to adopt analytic and inductive approaches to inquiry. Although the evidence from Suchman's efforts to train children in such methods is scant, the teacher at higher grade levels may gain better results.[18]

Teaching in the Elementary School. This study also has implications for the teaching of science at the elementary level as well as at the secondary level. It is agreed that some of the habits of inquiry should be instilled in very young children. It may well be that it is already too late to attempt inquiry teaching at the high school level without an earlier program which recognizes the open-ended nature of science. The character of the classroom inquiry analyzed in this study seems to indicate an over-riding tendency of students to present correct answers and win approval. All else seems subordinate to that end; the confrontation with the problem, the excitement of the search, and the challenge of exploration into unknown areas. A challenge to an answer which a teacher had already affirmed appeared unthinkable.

The disposition acquired through an inquiry oriented science education should be one which would challenge even the answer of

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[18] J. Richard Suchman, The Elementary School Training Program in Scientific Inquiry, U. S. Office of Education, Title VII Project Number 216 (Urbana, Illinois: College of Education, University of Illinois, June, 1962), pp.76-81.

an authority such as the teacher. For students with such a disposition, answers are merely starting points for further inquiry. It is perhaps in the elementary school that the initial encouragement of such a disposition must appear.

For Further Conceptual Development

A Dominant Group Disposition. Perhaps the most significant finding of this study related to the particularly stagnant manner in which the more powerful varieties of questions were used by students. It has already been explained that an assumption underlying the Suchman model is that students trained in inquiry would adopt a more analytic and inductive approach to inquiry. Such an approach would concentrate upon first identifying and analyzing problem parameters and then utilize the power of the experimental manipulation of variables to arrive at hypothetical relationships. Students in this experiment were quite inept at such a systematic and logical approach. In fact the experimental type of question was rarely used for anything, except to win approval at a time when the relationship already was determined.

This finding has considerable significance for the science educator. Advocates of the inquiry approach would certainly not quarrel with the value of laboratory inquiry in the secondary school. However, it appears valid to suggest that inquiry in the laboratory presupposes the ability to state verbally the operation about to be performed. The argument is not being advanced that all thinking is tied to verbalization, but only that the sequence of manipulative operations performed in the laboratory presupposes the ability to

state what is being done. Since the grade eight students demonstrated rather low ability to exercise such a verbal function, the suggestion has been offered that experimental practice must be provided at a much earlier level to ensure successful inquiry both in and out of the laboratory.

To support this claim, it was also found that in Group A, the expositional group, questions analogous to experimentation (concrete-inferential implication questions) were used with a frequency significantly higher than in any other group. An analysis of the transcripts of the other three groups revealed that although fifteen questions of "elimination" and sixteen questions of "addition" were asked by the combined classes in a total of fifty-four periods of inquiry, in only four instances were any of these thirty-one questions posed prior to the discovery of the fundamental relationship of the problem. This fact, combined with that of the expositional group's far exceeding the other three groups in the use of such questions, is striking.

Experimental manipulation of variables has become, as early as grade eight, a tool of exposition rather than of inquiry. Students appear to use this potentially powerful method of data searching and processing only in instances calculated to reemphasize the correct answer and thus win external approval. Searching seems already to have been associated only with extrinsic motives. It appears that previous training has either created or nurtured what Bion has called a "dependent" group culture.[19] Members of such a group are content to seek

[19] W. R. Bion, Experiences in Groups and Other Papers (London: Tavistock Publications (1959) Limited, 1961), p.74.

approval from an external parent-figure. Self motivation is either lacking or much subordinated to the motivation towards approval from the external authority. Such a disposition is perhaps the antithesis of that required for productive inquiry. A reorientation of early training to aid students to rise above the dependent culture would perhaps also aid them to use methods of experimentation _for the purpose of discovery rather than verification of presented fact_.

Inquiry and Risk. Related to the discussion of the dependent culture is the concept of risk-taking as it applies to inquiry strategy. Bruner has identified the element of risk as a significant factor in the adoption of a particular strategy in concept formation.[20] Risk was also found to be a convenient concept for the explanation of the devaluing, through inappropriate use, of certain question types by students in this experiment. It was suggested that verification questions were asked to an extent greater than could be predicted because they were being used for purposes other than the mere identifying and classifying of items. It appeared that they were low-risk avenues for the postulation, indirectly, of more hypothetical relationships and inferences.

In an open-ended inquiry setting the concept of risk is perhaps meaningful only because of a perceived external authority. With a more appropriate disposition to inquire, consequences of a verbal thrust would have positive value even when the speculation was incorrect.

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[20] Jerome S.Bruner, Jacqueline J. Goodnow and George A. Austin, _op. cit._, p.84.

Even the incorrect thrust would elicit information. The disposition acquired from a dependent culture would recognize risk in contemplated action since such action would be judged by external agents.

The group given instruction regarding the appropriate behavior in the hypothetical mode responded with greater fluency. However, they were equally inept at using such increased verbal interaction. Having identified the behavior which was to be rewarded, participation, they participated with greater willingness. It appears that the participation was completely geared to a low-risk approach in recognition of external motivation.

The Suchman Model: Logic vs. Psychologic. Two of the conceptual implications of the results of this study have now been discussed. The problem of the group disposition and the problem of risk in inquiry must be the concern of any study involving hypothetical modes of teaching. Related to both of these implications is perhaps an important weakness of the Suchman model. This model is apparently a logical model developed from considerations of information processing. Study and analysis in terms of such a model tend to lead to some incongruities.

In the face of an extremely complex task of assimilation, the reaction predicted by the logical model would be verification and analysis with gradual movement towards the postulation of relationship as data is accumulated. The actual behavior appeared to be emotional and, to large degree, non-rational. Subjective interpretations gave rise to intuitive guesses as to the immediate resolution of the problem. Emphasis seemed to be governed by a predisposition to seek the correct

behavior, that is, the behavior which would be rewarded by affirmation and approval. There was little tendency to accept the challenge of the search on its own merit. A logical model makes little provision for such observed behavior.

The logical function of different question types would predict the use of questions for particular purposes. But the evidence does not support such prediction. For example, it was suggested that questions of verification seemed to be used to satisfy intuitive guesses. Often the reiteration of a simple question of verification appeared to have no other function than to allow participation in a manner which would guarantee approval. That logical verification functions were not the primary functions of such questions was especially noticeable when pieces of apparatus peculiar to the science classroom were being identified. For example, a question such as, "That thing that you charged up with the ebonite rod, was that an electroscope?", seems to preclude the possibility that the question is actually aimed at verification. Consider the evidence from the question itself. An ebonite rod which had not been named was correctly identified. The process of charging had been assumed. It seems clear that the concept of electrostatic charge, which had been covered in the school curriculum prior to the experimental period, was fairly well understood by the inquirer. What, then, was the purpose of such a question? It appears that the learner uses such a question to serve functions other than those attributed to the question type by the logical model. This disposition towards approval, the tendency to minimize risk, and the subordination of intrinsic motives may well be the more important considerations.

The degree to which the influence of a student leader is a factor in the productivity of inquiry again follows a pattern unrelated to logical inquiry behavior. In the face of evidence which clearly indicates a lack of value in pursuing a given line of questioning, students blindly follow the leader. Such behavior is obviously tied more closely to the emotional group climate of the classroom than to the rational problem solving approach described by a logical model.

The lack of goodness of fit of questions to the categories identified by the model was also a factor which gave rise to certain difficulties. It is very likely that no logical model could adequately describe the inquiry behavior of students in a classroom. Establishing categories on the basis of a model which suggests hypothetical questions for which the intent is clear and the content simple is far removed from using the categories to describe the actual questioning of students, questioning loaded with concerns other than logical, exhibiting a complex mix of thought units.

Finally, a logical consideration of classroom inquiry would predict that a student's perception of independence in the teaching-learning process would be closely related to his behavior. This was not observed to be the case. The degree to which a student perceived that independence of action ought to be his prerogative indicated nothing about his commitment to act. This observation is supported by the increased participation due to instruction which was discussed above. An increase in fluency which was unaccompanied by more productive inquiry patterns indicates, perhaps, that the instruction served merely to impress upon the students that verbal participation was the behavior

considered appropriate by the teacher. Yielding to the disposition to be correct led to increased participation. But the participation was still designed primarily to gain the approval of the classroom authority rather than to increase the power of inquiry. Instruction, apparently, had indicated merely the appropriate way to gain approval.

Such incongruities between the model and the actual inquiry behavior of the students must lead to speculation about the value of the model. It is proposed that the behavior of students in an inquiry environment is so contaminated with affective factors that no model of inquiry based purely on logical presuppositions can predict or describe it effectively. From the Dewey model of thinking, whose familiar five problem solving steps so long dominated science texts, to the more recent paradigms based on computer technology, all such analogies to thinking are more or less adequate in that they are purely logical. Whenever logical structures are used to analyze data dominated by psychological influences, these will be found to be lacking in salience in this fundamental area. A more useful model of inquiry would incorporate both logical and psychological parameters.

Logical models are valuable nonetheless. The findings of this study, including the speculation on the disadvantages of a logical model, are presented in the light of such a model. Actual data can be compared against an ideal even though the ideal chosen at the moment might be selected on the basis of an incorrect assumption about the logical nature of inquiry. Devons and Gluckman address themselves to this problem of selection of a model.[21] They claim that the naivety

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[21]Ely Devons and Max Gluckman, "Conclusion: Modes and Consequences of Limiting a Field of Study," Closed Systems and Open Minds, Max Gluckman, editor (London: Oliver & Boyd, 1964), pp.158-261.

and circumscription of any model is a necessary evil in the analysis of social systems. The logical model of inquiry allows some degree of closure, completeness and prediction and, in this respect, it is useful. But as Devons and Gluckman further suggest, the closed system is a valid system only when used with an open mind. Studies of inquiry behavior based on logical models would do well to recognize the central importance of factors apparently unrelated to logic.

For Further Research

(a) The interaction between individual inquiry strategies and the individual's participation in the group appears to be an unexplored area. Following group inquiry, the identified non-participants might be subjected to further investigation involving Brunerian concept formation tasks or the Suchman individual inquiry sessions. Such a study might reveal much about the nature of individual inquiry which would aid the classroom teacher as well as the theorist.

(b) The independent variables used in this study were, for the most part, ineffective as predictors of inquiry. Yet it appears intuitively obvious that certain personality dimensions, involving independence, aggressiveness and stereotypy, are related centrally to inquiry behavior. This suggests a crucial area for further study.

(c) A study employing techniques being used in the area of group dynamics would provide considerable direction for the teacher who must be an effective leader of group inquiry. Identification of group leaders, isolates, cliques, and cohesiveness would all give guidance to the inquiry teacher.

(d) A study of the effect of different teacher personality patterns upon the inquiring behavior of a group would be valuable. This study recognized the domination which some teachers exert during class inquiry but was ineffective in determining the consequences, if any, of the past experience of the group with the particular teacher upon present attempts at inquiry oriented teaching. Further study in this area would, perhaps, include measures of authoritarianism and dogmatism, as well as ability.

(e) A critical need exists for instruments that would measure group inquiry operations with greater statistical confidence. Such instruments might well encompass the dimensions of individual inquiry in highly structured situations and group inquiry in free, open-ended discourse. Further study devoted to this end might be fruitful.

(f) It would appear that the study of group inquiry would be enhanced by particular information that could be obtained through visual recordings. For instance, in the present study identification of participants was gained through sound recordings alone. Many students had raised hands to volunteer responses but were not recognized by the teacher. Nevertheless, these students may well have been "actively" participating in the resolution of the problem. Such additional data would likely strengthenfurther study of total class inquiry behavior.

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APPENDICES

APPENDIX A

FILM 1 - BOILING WATER BY COOLING

RELATIONAL CONCEPTS

1. Vapor Pressure: At the surface of liquids, vapor is constantly being formed and being condensed back into liquids. For any given liquid the pressure of the vapor formed is a function of the temperature at the surface and of the nature of the liquid. Vapor pressure and temperature vary directly with each other.
2. Change of State (condensation): Gases, when cooled sufficiently, condense into a liquid state.
3. Boiling Point: When the temperature of a liquid has been raised to the point where its vapor pressure is equal to or greater than the pressure being exerted on the surface of the liquid, the vaporization of the liquid will occur within it as well as on its surface. The temperature at which this rapid internal vaporization occurs for a given liquid is known as the boiling point. The boiling point is a function of the pressure within the liquid.
4. Conduction of Heat: Heat may be conducted through objects or from one object to another by direct contact. Materials vary in the rate at which they will conduct heat.
5. Newton's Second Law: The motion of an object is changed by the action of an unbalanced force.

FILM 2 - THE FOUNTAIN (AN EXAMINATION OF THE PRINCIPLE OF THE SIPHON)

RELATIONAL CONCEPTS

1. Newton's First Law: An object tends to retain its state of motion unless acted upon by an unbalanced force.
2. Atmospheric Pressure: Air has weight. The pressure exerted (by the weight of the air) upon objects in the atmosphere is a function of the depth (or altitude) at which the object is placed. It is exerted equally in all directions at any given depth.
3. Incompressibility and Nonextendability of Liquids: Most liquids can only be negligibly compressed or extended by altering the pressure applied to them. They will transmit pressure equally in all direction.
4. Liquid Pressure: The pressure exerted by a liquid upon objects immersed in it is a function of depth. The pressure is exerted in all directions at any given depth.

FILM 3 - PHOTOELECTRIC EFFECT

RELATIONAL CONCEPTS

1. Nature of Electric Charge: There are two kinds of electric charge. Objects carrying a like charge repel each other. Those carrying an unlike charge attract.

2. Divisibility of the Atom: Atoms are constructed of smaller particles, some charged and some uncharged. Forces can be generated to remove particles from atoms.

3. Photoelectricity: Light can interact with the electrons of certain atoms, in some instances by removing them entirely. This action leaves the material with a net positive charge.

4. Newton's Second Law: The motion of an object is changed by the action of an unbalanced force.

FILM 4 - THE VACUUM
(THE OPERATION OF A SIPHON IN AN EVACUATED BOTTLE)

RELATIONAL CONCEPTS

1. Newton's First Law: An object tends to retain its state of motion unless acted upon by an unbalanced force.

2. Gas Volume-Pressure Relationship: At constant temperature the volume of a given amount of gas by weight varies inversely with the pressure.

3. Atmospheric Pressure: Air has weight. The pressure exerted (by the weight of the air) upon objects in the atmosphere is a function of the depth (or altitude) at which the object is placed. It is exerted equally in all directions.

4. Incompressibility and Nonextendability of Liquids: Most liquids can only be negligibly compressed or extended by altering the pressure applied to them. They will transmit pressure equally in all directions.

FILM 5 - THE CARTESIAN DIVER

RELATIONAL CONCEPTS

1. Archimedes Principle: A body immersed in a liquid is buoyed up by a force equal to the weight of the displaced volume of the liquid. This force is also equal to the difference in downward and upward pressures on the immersed body that result from the difference in depth between the top and bottom of the object.
2. Newton's Second Law: The motion of an object is changed by the action of an unbalanced force.
3. Gas Volume-Pressure Relationship: At constant temperature the volume of a given amount of gas by weight varies inversely with the pressure.
4. Liquid Pressure: The pressure exerted by a liquid upon objects immersed in it is a function of depth. The pressure is exerted equally in all direction.
5. Incompressibility of Water: Water cannot be compressed. Pressure applied to water in a closed system will be transmitted equally in all directions at any given depth.
6. Displacement: Two objects or substances cannot occupy the same space at the same time.

FILM 6 - THE BURNING CANDLE
(THE COMPOSITION OF AIR IN A JAR INVERTED OVER WATER)

RELATIONAL CONCEPTS

1. Combustion, A Chemical Reaction: When a substance burns in the presence of oxygen part of this substance usually combines with the oxygen to form a new substance. When a candle burns some of the oxygen combines with carbon in the candle to form a gas called carbon dioxide. Some of the oxygen combines with hydrogen from the candle to form water. In combustion or any chemical reaction material is not "used up," but is merely changed in form.

2. Newton"s Second Law: The motion of an object is changed by the action of an unbalanced force.

3. Displacement: Two objects or substances cannot occupy the same space at the same time.

4. Atmospheric Pressure: Air has weight. The pressure exerted by the air upon objects in the atmosphere is a function of the depth (or altitude) at which the object is placed. It is exerted equally in all directions.

5. Vapor Pressure: At the surface of liquids, vapor is constantly being formed and being condensed back into liquids. For any given liquid the pressure of the vapor formed is a function of the temperature at the surface and of the nature of the liquid. Vapor pressure and temperature vary directly with each other.

6. Boyle's Law: At constant volume the pressure of a gas varies directly with its temperature. At constant pressure the volume of a gas varies directly with its temperature. At constant temperature the pressure of a gas varies inversely with its volume.

APPENDIX B

Q - SORT INSTRUMENT

The Q-sort instrument administered to each student as pre and post experiment tests contained the following materials: 28 tasks, each listed on a separate 3 x 5 index card, numbered from 11 through 38 and arranged in random order; 1 instruction and answer sheet designed for the You-Sort; and 1 instruction and answer sheet designed for the Teacher-Sort.

The tasks, and the subscore categories to which they belong (in parentheses), are as follows:

11 determine how the student is progressing, how well he is doing apart from examinations. (evaluation)

12 decide on how the student's final grade is to be determined. (evaluation)

13 decide on how the student can deal with those areas in which he is weak. (evaluation)

14 decide what students would investigate certain problems arising out of class activities. (evaluation)

15 determine ways in which the student can make better progress in the science course. (evaluation)

16 see that the student takes good notes in the course from class lectures, readings and films. (evaluation)

17 identify ways in which the course could be improved and made more interesting. (evaluation)

18 decide whether the student needs special help. (evaluation)

19 decide what the student can expect to learn in class. (learning experiences)

20 see that the student understands the laws and ideas of science in the course. (inquiry)

21 see that the student knows how to use the laws of science to explain new situations and solve new problems. (inquiry)

22 see that the student is familiar with newer problems, ideas and laws of science outside the course textbook. (inquiry)

23 think up experiments that would test the laws of science discussed in class. (inquiry)

24 interpret the results of experiments done in class. (inquiry)

25 draw conclusions from experiments and demonstrations conducted in the course. (inquiry)

26 identify and define the question which an experiment or demonstration is supposed to answer. (inquiry)

27 determine when the student has enough information, and of the right kind to answer the question in a problem. (inquiry)

28 decide the exact procedure or way an experiment will be done in class. (inquiry)

29 raise questions that challenge the conclusions drawn by other students from experiments done in class. (inquiry)

30 locate other reference materials such as books, articles in magazines, etc., that are related to the course. (learning experiences)

31 select the experiments and the demonstrations to be done in the course. (learning experiences)

32 identify the chapters, pages, etc., in the textbook, magazines and other books that are related to the course. (learning experiences)

33 determine what kind and how much homework is done by the student. (learning experiences)

34 determine whether students or teacher do a given demonstration or experiment. (learning experiences)

35 decide whether the amount and quality of work done in an assignment are adequate. (learning experiences)

36 determine what kind and how much use the student makes of the available equipment for science. (learning experiences)

37 make certain that the class pays attention. (learning experiences)

38 decide whether and how a student is disciplined. (learning experiences)

The two instruction and answer sheets appear on the following pages. During administration of the You-Sort the students were instructed to sort the tasks according to the instruction, "Who do YOU think ought to ...?" The cards were divided into four or less groups as represented by the four divisions of the answer sheet. Then the number of each task sorted into a division was placed in one of the

squares. The student's name was printed at the top of the sheet. For the Teacher-Sort an analogous procedure followed the instruction, "Who would you say your TEACHER thinks ought to ....?"

ACHIEVEMENT TEST

This test was administered to students as a pre and post experiment test. All answers were to be completed within a twenty minute time period. Students were encouraged to guess rather than omit an unknown item. A separate answer sheet was provided.

1. Water will normally boil when its temperature is;

   a) less than 100 degrees Centigrade.
   b) 100 degrees Centigrade.
   c) more than 100 degrees Centigrade.
   d) neither of these.

2. As the temperature of a liquid is increased;

   a) its vapor pressure decreases.
   b) its vapor pressure increases.
   c) its vapor pressure remains the same.
   d) its vapor pressure changes in no set way.

3. At the normal boiling point, vapor pressure;

   a) is less than atmospheric pressure.
   b) is greater than atmospheric pressure.
   c) is equal to atmospheric pressure.
   d) neither of these.

4. High in the mountains the boiling temperature of any liquid is;

   a) higher than normal.
   b) the same as normal.
   c) lower than normal.
   d) dependent on the kind of liquid.

5. Four identical pans containing equal amounts of water at room temperature are placed, one in each of four ovens at 50 degrees, 80 degrees, 100 degrees and 200 degrees. After 20 minutes the pan with the most water is in the oven at;

   a) 100 degrees.
   b) 200 degrees.
   c) 50 degrees.
   d) 80 degrees.

6. A small amount of water is boiled in a liquid wax can for some time, allowing steam to fill the can above the water. The small screw cap is then fitted tightly and the can is placed in cold water. The can crushes inward because;

a) it was weakened by the heating.
b) the steam inside causes the can to burst.
c) the steam inside changes to water.
d) neither of the above.

7. When drinking liquid with a straw, the liquid moves due to;

a) suction in your mouth.
b) reduced pressure in your mouth.
c) increased atmospheric pressure.
d) atmospheric pressure outside your mouth.

8. An inflated balloon is sitting in a tightly sealed glass jar connected to a vacuum pump. As the air is pumped out of the jar;

a) the balloon grows larger.
b) the balloon stays the same size but rises in the glass jar.
c) the balloon shrinks in size.
d) neither of these.

9. A pump lifts water from a low level to a higher one by creating a vacuum in the pipeline into which water flows. Such a pump can lift water only about 30 feet because;

a) the vacuum created by the pump is not strong.
b) no vacuum can lift water this high.
c) at 30 feet the water pressure equals air pressure.
d) neither of these.

10. When light is used to cause electrons to move, the current is called;

a) thermoelectricity.
b) photon flow.
c) induced electricity.
d) photoelectricity.

11. When light rays strike certain kinds of metals, electrons are emitted from the metals leaving them;

a) positively charged.
b) uncharged.
c) negatively charged.
d) neither of these.

12. In question 11. we learn that light can knock electrons away from the atoms of some metals. If an electroscope were made of such a metal and was positively charged, then placing it in strong light would;

   a) cause the leaves to spread further apart.
   b) cause no change in the leaves.
   c) cause the leaves to close.
   d) cause the leaves to close and open again.

13. If the leaves of an electroscope, spread apart because of a negative charge, began to close together;

   a) negative charges must be flowing onto the leaves.
   b) positive charges must be flowing off the leaves.
   c) positive charges must be flowing onto the leaves.
   d) negative charges must be flowing off the leaves.

14. Light meters in cameras work because of the action of light rays on sensitive metals. The greater the amount of light, the greater the deflection of the needle and;

   a) the more electrons displaced.
   b) the less the current that flows.
   c) the fewer the number of photons.
   d) neither of these.

15. An object floats when it;

   a) displaces more water than its own weight.
   b) displaces less water than its own weight.
   c) displaces a weight of water equal to its own.
   d) neither of these.

16. Two air-filled balloons of identical size at room temperature are tied to the bottoms of two tanks of water at the same temperature. If one tank is filled to a depth of four feet and the other to twelve feet;

   a) the balloon in the four foot tank will be larger.
   b) the balloons will remain the same size.
   c) the balloon in the twelve foot tank will be larger.
   d) the balloons in the two tanks will be larger.

17. A submerged submarine can surface by allowing compressed air to expand into tanks filled with water, forcing the liquid out. It then rises because;

   a) it weighs less than before.
   b) it displaces more water than before.
   c) air always rises in water.
   d) neither of these.

18. A small ball of aluminum foil sinks to the bottom of a glass of water. If the foil is straightened out and shaped like a box it will float because;

a) boxes usually float.
b) it is now not so heavy.
c) the water now has more surface to push on.
d) it displaces more water than before.

19. Two balloons, inflated to identical sizes at the same temperature, are taped to the bottoms of two bottles, one in each bottle. One bottle is filled with water, the other with air. The mouths of the two bottles are covered by a tightly fitted, air-tight rubber sheet. If you press equally hard on the two rubber covers;

a) the balloon in the air would get smaller than the other.
b) the balloon in the water would get smaller than the other.
c) both balloons would get smaller by an equal amount.
d) both balloons would get larger by an equal amount.

20. Air contains approximately;

a) 50% Oxygen.
b) 80% Oxygen.
c) 30% Oxygen.
d) 20% Oxygen.

21. If a candle burns in a small closed container of air, it will go out when;

a) ALL of the air is used up.
b) ALL of the oxygen is used up.
c) ALL of the carbon dioxide is used up.
d) neither of these.

22. Two air-filled balloons of identical size at room temperature, are tied to the bottoms of two pans of water. If one pan is at 100 degrees, the other at 50 degrees;

a) the balloon in the 100 degree pan will be the smaller of the two.
b) the reverse of (a) will be true.
c) both balloons will be smaller but equal in size.
d) both balloons will be larger but equal in size.

23. As a candle burns in a small closed space, it uses part of the air but produces certain gases which replace some part of the used up air. If the useable part of the air was 1/5 of it, the volume would change by;

a) less than 1/5.
b) more than 1/5.
c) exactly 1/5.
d) neither of these.

24. When gases ignite rapidly, as in an explosion, the great expansion of gases is caused by;

a) the noise.
b) the heat.
c) the smoke.
d) neither of these.

APPENDIX C

The following transcripts of inquiry were taken from the tape recordings of the question periods following the presentation of Film 1, Boiling Water by Cooling to Class 06, Group B, and to Class 08, Group C. Each period of inquiry was transcribed, coded and summarized in the manner of the following examples. The code used for analysis of question type was as follows:

QUESTION	TYPE	CODE
VERIFICATION QUESTIONS	CATEGORICAL VERIFICATION	
	Nominal	NOM
	Normative	NORM
	ANALYTICAL VERIFICATION	
	Condition-Descriptive	DESCRP
	Condition-Comparative	COMPAR
	Structural-Component	COMPON
	Properties Check	PROP
IMPLICATION QUESTIONS	ABSTRACT-CONCEPTUAL	
	Diffuse	DIFFUSE
	Directed	DIRECT
	CONCRETE-INFERENTIAL	
	Elimination	ELIM
	Substitution	SUBS
	Addition	ADD
	CONCRETE-CONCEPTUAL	CONCEP

GROUP B

CLASS 06

FILM 1 - BOILING WATER

No. Students present 32

Total time for inquiry session . . . . 9 min. 30 sec.

Total number questions (q) 25

Total number participants (p) 10

ANALYSIS BY QUESTION TYPE

	00 - 05 min.			05 - 10 min.		
	q	%	p	q	%	p
NOM	1	6.6	1			
NORM						
DESCRP	1	6.6	1	2	20	1
COMPAR						
COMPON						
PROP				1	10	1
DIFFUSE	1	6.6	1			
DIRECT	10	66.6	5	7	70	5
ELIM	1	6.6	1			
SUBS						
ADD						
CONCEP	1	6.6	1			
TOTAL	15		10	10		7

B - 03 - 1.1

Naomi	Was there steam in the flask when the stopper was put in first?	DESCRP
	Ans. Yes, I suppose you'd have to say there was.	
Lorraine	Would the water boil if the stopper wasn't on it when you poured cold water on it?	ELIM
	Ans. No.	
John	Was the stopper put on it to keep the warm air in and vapor?	DIRECT
	Ans. Well, I suppose you could say this was one of the reasons it was. The main one, as a matter of fact.	
....	Did pouring the cold water on the flask heat the water?	DIRECT
	Ans. No.	
Brian	Did the cold water, let's say, shrink the beaker so that the hot water started to move faster, started to boil? It contracted the beaker?	DIRECT
	Ans. No.	
Brian	Is it the relationship between the boiling point and the outside temperature? There is a relationship isn't there?	DIFFUSE
	Ans. Not between the b.p. and the outside temperature. No.	
......	Well was that action boiling or was it just bubbling?	NOM
	Ans. Boiling, as evidenced by the bubbles.	
.....	Then there would be steam wouldn't there, at the top?	PROP
	Ans. There was steam as you noticed.	
Stan	Didn't the cold water cool down the steam and made sort of vacuum and the water wouldn't be so hard to boil? The pressure doesn't seem to be on it?	DIRECT
	Ans. That's pretty good. (Student requests repeat)	

.....	Well see, when you pour the cold water on, it turns the steam that's in the flask to water. And water doesn't take up as much room as steam so it's sort of a vacuum. Less pressure on it and it doesn't have to be so hot to boil?	DIRECT
	Ans. That's pretty good. Anyone see any difficulties with it?	
Howard	It would still have to be hot though, wouldn't it?	CONCEP
	Ans. Comparatively, yes.	
Brenda	Well, if it was actually boiling and giving off steam and everything, wouldn't that force the cork off?	DIRECT
	Ans. Not if you were watching the way it was done. Think of when the cork was placed in.	
.....	Did the cold water build up pressure inside the jar?	DIRECT
	Ans. No.	
Brian	Did the cold water lower the pressure?	DIRECT
	Ans. You're going to have to explain what you mean by pressure here.	
.....	Well the force inside the beaker, the steam. Did the cold water lower the pressure in the beaker where the steam was?	DIRECT
	Ans. Yes, I suppose you could say it did.	
Harold.	Did this low pressure allow the hot water to rise and bubble?	DIRECT
	Ans. This term rise sort of bothers me, I'd have to say no to that I think.	

FIVE MINUTES

Bruce	Well water boils and the more pressure there is on it it doesn't boil as easily. So if you had a lot of pressure on it, then it wouldn't boil. But if you lessened the pressure, by changing the steam back to water, then it would boil again. But actually it's still at the same temperature?	DIRECT
	Ans. Water's always at the same temperature?	
.....	Well it's slowly going down? The temperature of the water?	DESCRP
	Ans. That's pretty close.	
Stan	Yeah, well it's sort of like when you have, - when you're boiling water on a high mountain, there's not so much air pressure and so it will boil at a lower temperature?	DIRECT
	Ans. Yes, that's true.	
Bruce	So, all you're doing is changing the pressure on it so it boils easier?	DIRECT
	Ans. Yes, that's true, Bruce.	
Jean	Could it be that when the water was hot, it was still hot, and so when you poured the cold water on the flask the air pressure is lowered, and so it's lowered to the point where its boiling, the water is boiling again?	DIRECT
	Ans. Yes, I would say that's pretty close to being correct.	
Naomi	Is it that the cold water contracted the molecules in the flask and that lowered the pressure?	DIRECT
	Ans. Yes, cold water contracted molecules lowering the pressure.	
Harold	Doesn't hot water have to expand to boil?	CONCEP
	Ans. Yes, I'll take the boil part anyway. (encouragement to sum up)	
.....	The low pressure contracted the water molecules which expanded the water in the flask to boil?	DIRECT
	Ans. That word expanded is going to have to make me say no.	

B - 03 - 1.4

Bruce — The cold water changed the steam back to water causing low pressure in the beaker and so the water boiled because there was less resistance to the boiling? DIRECT

Ans. That's pretty good. Any other questions?

GROUP C

CLASS 08

FILM 1 - BOILING WATER

No. Students present 35

Total Time for inquiry session . . . . 10 min. 15 sec.

Total No. Questions (q) 34

Total No. Participants (p) 14

ANALYSIS BY QUESTION TYPE

	00 - 05 Min.			05 - 10 Min.		
	q	%	p	q	%	p
NOM	6	37.5	6	1	7.15	1
NORM						
DESCRP	1	6.3	1	2	14.3	2
COMPAR				1	7.15	1
COMPON						
PROP				1	7.15	1
DIFFUSE	1	6.3	1	1	7.15	1
DIRECT	8	50	6	8	57.1	5
ELIM						
SUBS						
ADD						
CONCEP						
TOTAL	16		11	14		9

.....	Was this stuff that they poured from the beaker, alcohol?	NOM
	Ans. No, it could be, but the answer would be no.	
Darlene	Was it hot water?	NOM
	Ans. No.	
Mary	Was it cold water?	NOM
	Ans. Yes.	
Boisvert	Is this trying to prove condensation or something goes on?	NOM
	Ans. No.	
Wilson	Is this trying to prove that when water cools it contracts?	NOM
	Ans. Could be.	
Routier	Was it water that he poured over the beaker?	NOM
	Ans. Yes.	
Keith	The reason he put the stopper on was because he didn't want the moisture to escape, wasn't it?	DIRECT
	Ans. No, I don't think so.	
Mary	Is it to stop the heat from escaping from the beaker?	DIRECT
	Ans. Not necessarily.	
Dave	When there's not much air pressure water boils at a lower temperature, is this it?	DIRECT
	Ans. Yes. Any further questions.	
.....	Was it hot water they poured over the flask?	
	Ans. The question's been answered several times. No.	
Wendy	Did pouring cold water over the flask of hot water cause it to rise and cause the bottom or the lower half to be colder than the top, to rise and form bubbles?	DIRECT

	Ans. I can't answer that question because I don't know what you mean by rising.	
Wendy	Well, did it cause bubbles to rise from the bottom part of the flask?	DIRECT
	Ans. Well yes. I think your question could be answered yes.	
Bob	Well is the solution, that air inside the beaker, before the top was put on, it was hot, and it had expanded, and when you poured the cold water over it the air inside contracted, And made it smaller, so there was a little air pressure and it boiled?	DIRECT
	Ans. Yes. Yes.	
David	Is the reason for the boiling to reduce air pressure in the flask, after you put the stopper on?	DIRECT
	Ans. I don't know how to answer this. You're sort of half way. You're not asking me a direct question where I can answer. You're sort of half yes and half no.	
Keith	Was the stopper the reason for making the hot water boil again when the cold water was poured over it?	DIFFUSE
	Ans. Not the reason, but it helped.	
Wilson	When the stopper was put on it kept the pressure in and when it was heated it boiled at a lower temperature?	DESCRP
	Ans. No.	
Keith	When you poured the cold water on the hot water there, did it cause it to expand?	DIRECT
	Ans. No.	

FIVE MINUTES

Kurt	Well, when you put the cold water on the flask, did the water really boil?	DESCRP
	Ans. Yes.	

Keith	Is the reason the water boiled inside is because, the flask was hot when you took the amount of water, and you put the stopper on and then you poured cold water over it, it didn't allow any of the heat to escape from the flask?	DIRECT
	Ans. No.	
Mary	When the cold water met the hot water was the boiling a reaction?	NOM
	Ans. Yes. It was a reaction.	
Colin	Was it that when the water was hot it caused the glass to be warm and then when you poured the cold water over it the glass got cold but the water inside it rised up and caused it to go around, inside?	DIRECT
	Ans. No.	
Keith	When you got the burner under the flask and then you put the top on it, ... stopper, well that causes a certain amount of pressure inside the flask? Wouldn't it?	DIRECT
	Ans. Yes.	
.....	Then when you pour the cold water on the flask from the beaker do you --- do you ---	
Craig	When the water was boiled, oxygen in the water was heated and you poured the cold water over the top did that cause the hot air in the water to rise?	DIRECT
	Ans. No.	
Wendy	Does this experiment have something to do with elements like oxygen in the water and what happens to them?	DIFFUSE
	Ans. No. Well I'll correct that and I'll say partly, yes.	
Mary	When you poured the cold water over the flask was the result exactly the same as when you had the flame under it?	COMPAR
	Ans. Yes.	

Bob	Was the bubbling caused due to air pressure under the flask?	DIRECT
	Ans. Yes.	
Keith	When you put the flame under the flask it caused pressure inside, did it cause high pressure?	DESCRP
...	Ans. Yes.	
...	Well, when you put the cold water over the flask did it cause low pressure inside the flask?	DIRECT
	Ans. Yes.	
...	Is the pressure the reason it bubbled, the low pressure?	DIRECT
	Ans. Right, yes.	
Wilson	If the water, the pressure changed, like, when the water was poured over there was a low pressure and the water boiled, well, water boils at low pressures?	PROP
	Ans. Yes.	
...	So the change in pressure caused the water to boil?	DIRECT
	Ans. Yes.	